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CRUDE OIL STABILIZATION PROCESS

EL PROCESO DE ESTABILIZACION DEL CRUDO

TITLE

Simulation and Design of the Topside of a Floating Production, Storage and Offloading vessel. (FPSO) (Crude Oil Stabilization Process)

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

After the industrial revolution in the early 20th century and the invention of cars, apart from coal, petroleum has been one of the most important source of energy in the world. Countries that produce crude oil make a lot of money from it until recently, when the crude oil price reduced due to the discovery of shale oil in the United States. Crude Oil or raw unrefined petroleum is basically a commonly combustible fluid of complex hydrocarbons found in reservoir underneath the Earth's surface. Unrefined petroleum is drilled from the well and sent to petroleum treatment facilities for it to be handled into oil based goods that are desired by the consumers. In any case, before being shipped to the treatment facilities at downstream, the raw petroleum should be settled and flashed off in advance since it contains light segments which are very volatile, that can evaporate easily if they have a high vapor pressure. Therefore, the crude oil need to be stabilized first to reduce wastage from evaporation during its transport to the onshore. In this Cendor Phase 2 Field case, the crude oil is stabilized at the topside of an FPSO (Floating Production Storage and Offloading vessel). This thesis plans to investigate and identify the factor in the process parameter that affects the final vapor pressure of the crude oil at Cendor Phase 2 Field, Malaysia.

In order to identify the effect of the parameters and the most optimum condition to ensure the vapor pressure of crude oil is reduced as much as possible, a simulation of the process has been carried out by utilizing Aspen HYSYS 8.8 (ver. 2011) simulator following the procedure provided in the Design Basis Memorandum of the project. It was discovered that at the feed, the inlet temperature, the feed volumetric flow rate, free water volumetric flow rate can give effect in the final RVP and TVP of the crude oil. Furthermore, it was also discovered that the operating pressure of 17.5 bar for High Pressure Separator, and 6 bar for Low Pressure Separator are suitable to produce crude oil that fulfills the vapor pressure requirement set by the client. Compositional analysis was also carried out at the end of this thesis, and it is discovered that the final composition of the crude oil is theoretically consistent with the reading of its TVP and RVP. In light of the parameters broken down, it can be concluded that those parameters that have been manipulated have a very noteworthy effect on the TVP and RVP of the crude oil.

1.1 CRUDE OIL PROCESSING AT UPSTREAM

In the oil field, crude oil–gas–water mixtures that are taken out from wells are usually directed, through pipe lines and manifold system, to a central process and treatment facility at the upstream. In most cases, the first primary process undergone by the produced crude oil is the separation. This separation process would separate the crude into three phases which are oil, gas, and water.[1]

This separation process would take place in mechanical devices referred to as separators. If the produced crude oil stream contains no water, two-phase separators would be used, while three-phase separators are used to separate produced crude oil with the presence of water. This gas–oil-water separation process done in these separators is very vital as it is considered as the backbone process in oil and gas operations.[1]

[1] This would ease separation of the gas from the oil. Separators are also used to separate the free water from the oil, when the water exits with the produced oil stream. Once all the separation process is done, each stream undergoes their respective processing procedure for further field treatment. The crude oil leaving the second separator may fulfill the requirement in terms of its volatility (vapor pressure), however, they do not necessarily fulfill the full clients' requirement. [1] The presence of this salt water presents serious corrosion and scaling issues in transportation and plant operations. [1]

The fluids existing in a hydrocarbon are usually under high pressure and may be in a liquid or gaseous state. The hydrocarbon fluids in the reservoir are normally in contact with water, which is normally salty [2]. [1] Each well head would also have their own unique condition. Based on reference [3], some of the parameters that would have an impact on how the final characteristic fluid will be and in what way they should be handled at the surface are as followings [3];-

a. Pressure.

b. Temperature.

c. Flowrates of the fluids.

d. Type and quantity of fluid that it contains e. Whether the fluid contains components considered to be undesirable (e.g., hydrogen sulphide, H_2S and carbon dioxide, CO_2).

f. Amount of free water in the crude.

1.2 OBJECTIVES

In this project, it is aimed to simulate a Crude Stabilization Process using the inlet crude composition of Cendor Phase 2 Field Project as the case study. The final product obtained from this simulation is a stabilized crude oil with maximum Reid Vapor Pressure (RVP) of 8 psia [4], following the requirement of clients for storage and transport. The simulation also aims to investigate the effect of each parameter stated, towards the final vapor pressure of the crude oil. Below are some of the objectives of this thesis to achieve the initial aim:-

1. Study on the detailed crude stabilization process done at the upstream and carry out process simulation using Aspen (HYSYS).
2. Compare different types of fluid package to calculate the RVP of the final crude oil product.
3. Construct different scenarios by varying different parameters (temperature, feed flowrates, and pressure) and compare the Reid Vapor Pressure (RVP) and True Vapor Pressure (TVP) of final products.
4. Observe the change in the composition of the crude oil when it is initially fed into the process and after it has been stabilized.
5. Study the correlation between the vapor pressure of the crude oil and its composition.

2.1 VAPOR PRESSURE

In the process of transporting a crude oil, one of the most important properties that need to be taken into considerations is the vapor pressure of the crude oil. For the ease of transport and handling of the crude oil, the vapor pressure needs to be as low as possible. From reference [5], vapor pressure or equilibrium vapor pressure can be defined as the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a certain temperature in a closed system. Vapor pressure indicates the tendency of particles to escape from the liquid (or a solid). In other words the equilibrium vapor pressure is a measure of a liquid's volatility. The pressure exhibited by vapor above a liquid surface is known as vapor pressure. As the temperature of a liquid increases, the kinetic energy of its molecules also increases [4]. As the kinetic energy of the molecules increases, the number of molecules transitioning into a vapor also increases, thereby increasing the vapor pressure [5].

2.1.1 REID VAPOR PRESSURE (RVP) AND TRUE VAPOR PRESSURE (TVP)

There are two types of methods in measuring the vapor pressure. The first one is Reid Vapor Pressure (RVP) and the other one is True Vapor Pressure (TVP). Based on reference [5], Reid Vapor Pressure [RVP] is a vapor pressure where the liquid or fuel does not eliminate air or water vapor from the sample. The reading includes the vapor pressure of the air and water vapor too whereas True Vapor Pressure (TVP), it eliminates air and water vapor from the sample at a specified temperature. Therefore, the reading of the vapor pressure only depends on the pressure exerted on the fuel itself. Typically, the Reid pressure will be lower than the True Vapor Pressure (TVP), because the dissolved water and air included in the sample container would affect the reading of vapor pressure.[5] In oil and gas industry, Reid Vapor Pressure (RVP) is widely used, but ultimately it depends on the requirement of the client and property of the crude oil at the field. Sometimes, True Vapor Pressure (TVP) method is also used. However, in a project, usually only one method is used to ensure the consistency of the analysis.

2.1.2 DEVELOPMENT OF MODEL FOR CORRELATION OF TVP WITH RVP OF CRUDE OIL

From reference [4], the correlations for conversion of processed oil and raw crude oil's RVP to TVP and vice versa, has been developed. These data covered the full ranges of temperature, RVP and TVP. The equations below can be used to calculate either RVP or TVP with the correct values of A, B, and C.

$$A = A_1 - A_2\, ln(RVP)$$
$$B = B_1 - B_2\, ln(RVP)$$
$$TVP = \exp\left(A - \frac{B}{T + C}\right)$$

TVP to RVP**:** Similarly this tip proposes the following equations for conversion from TVP to RVP.

$$A = A_1 - A_2 ln(TVP)$$
$$B = B_1 - B_2 ln(TVP)$$
$$RVP = \exp\left(A - \frac{B}{T + C}\right)$$

Equation 1. Where T is Temperature, °C (°F), RVP is Reid Vapor Pressure, kPa (psi), TVP is True Vapor Pressure, kPa (psia). Note that the values of A_1, A_2, B_1, and B_2 are different in the above two sets of equations. The value of "C" is a function of the chosen units (SI versus FPS) and is consistent [4].

Based on these calculation method, a type of graph called a nomograph has been established that permits Reid Vapor Pressure (RVP) data to be converted to True Vapor Pressure (TVP), and vice versa. These graphs are vital because it makes the conversion from one to another much easier for engineers in oil and gas industry. And in some cases, even though the Reid Vapor Pressure (RVP) is widely used in the industry, True Vapor Pressure (TVP) is needed for certain petroleum fuel properties. Therefore, the effects of air and water from the Reid Vapor Pressure (RVP) need to be eliminated from the pressure measurements.

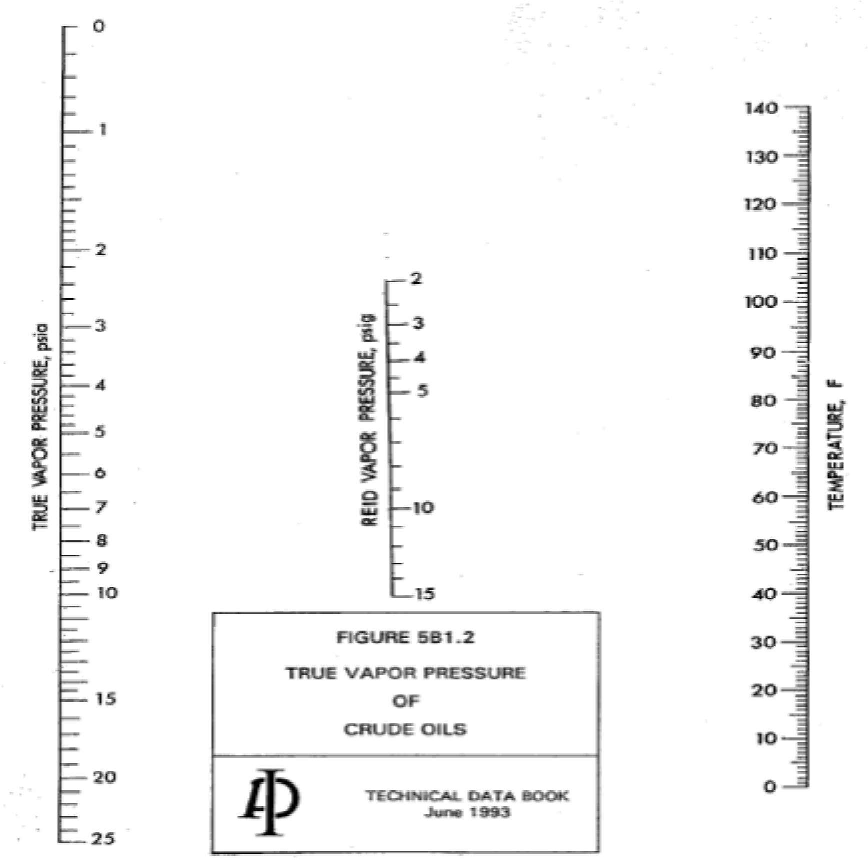

Figure 1. Nomograph for the conversion of RVP to TVP and vice versa [6].

Typically for crude oil, the approximate relationship between RVP and TVP at 37.8 °C are tabulated for few crude oil samples in the table below:-

RVP at 37.8 C	TVP at 37.8 C
psi	psia
5	5.8
6	6.8
7	7.9
8	8.9
9	9.9
10	11
11	12
12	13.1
13	14.1
14	15.2
15	16.2

Table 1. The approximate relationship between RVP and TVP at 37.8°C

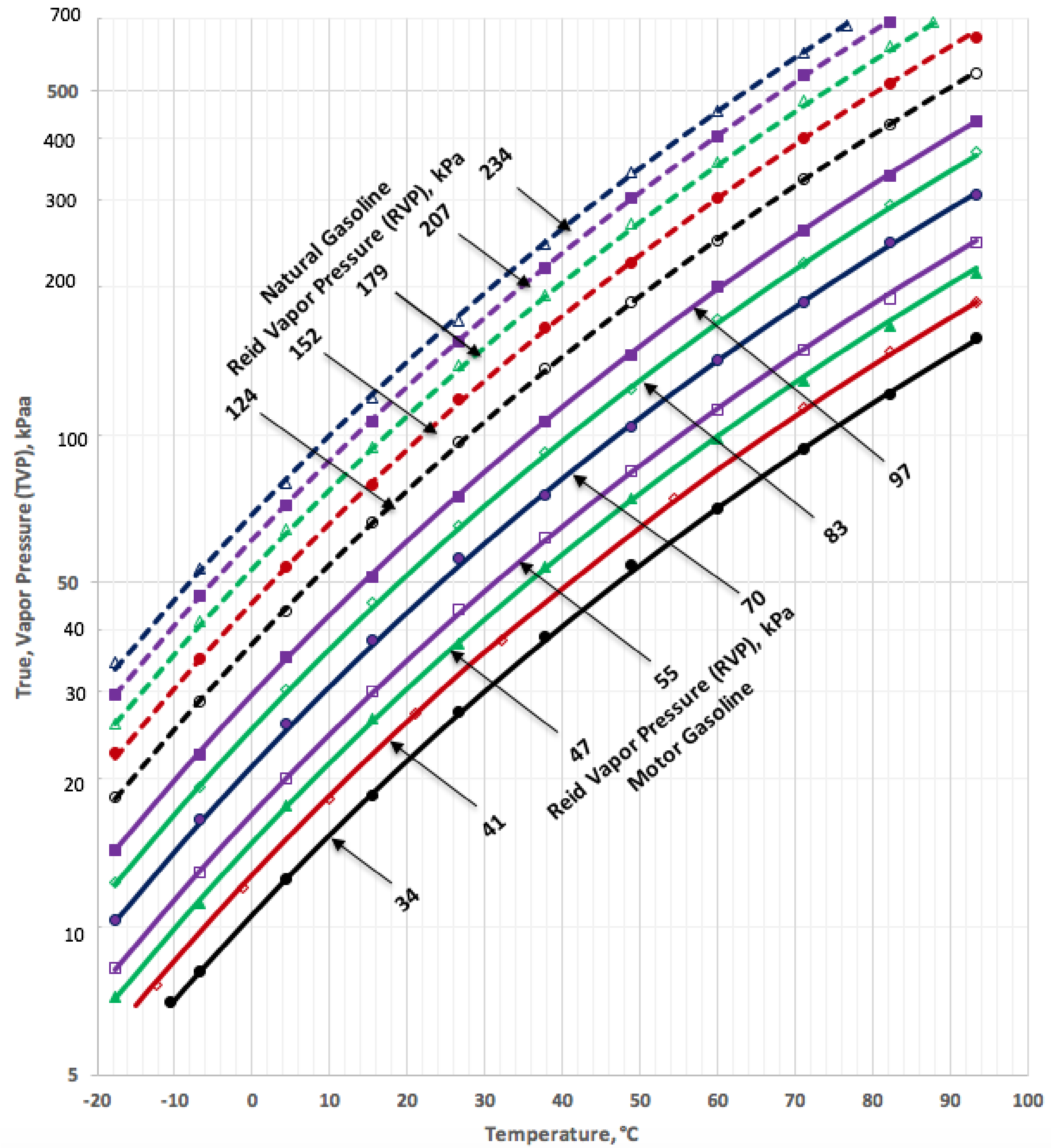

Figure 2. The approximate relationship between RVP and RVP for different volatile crude and petroleum products is given by W L Nelson in reference[2]

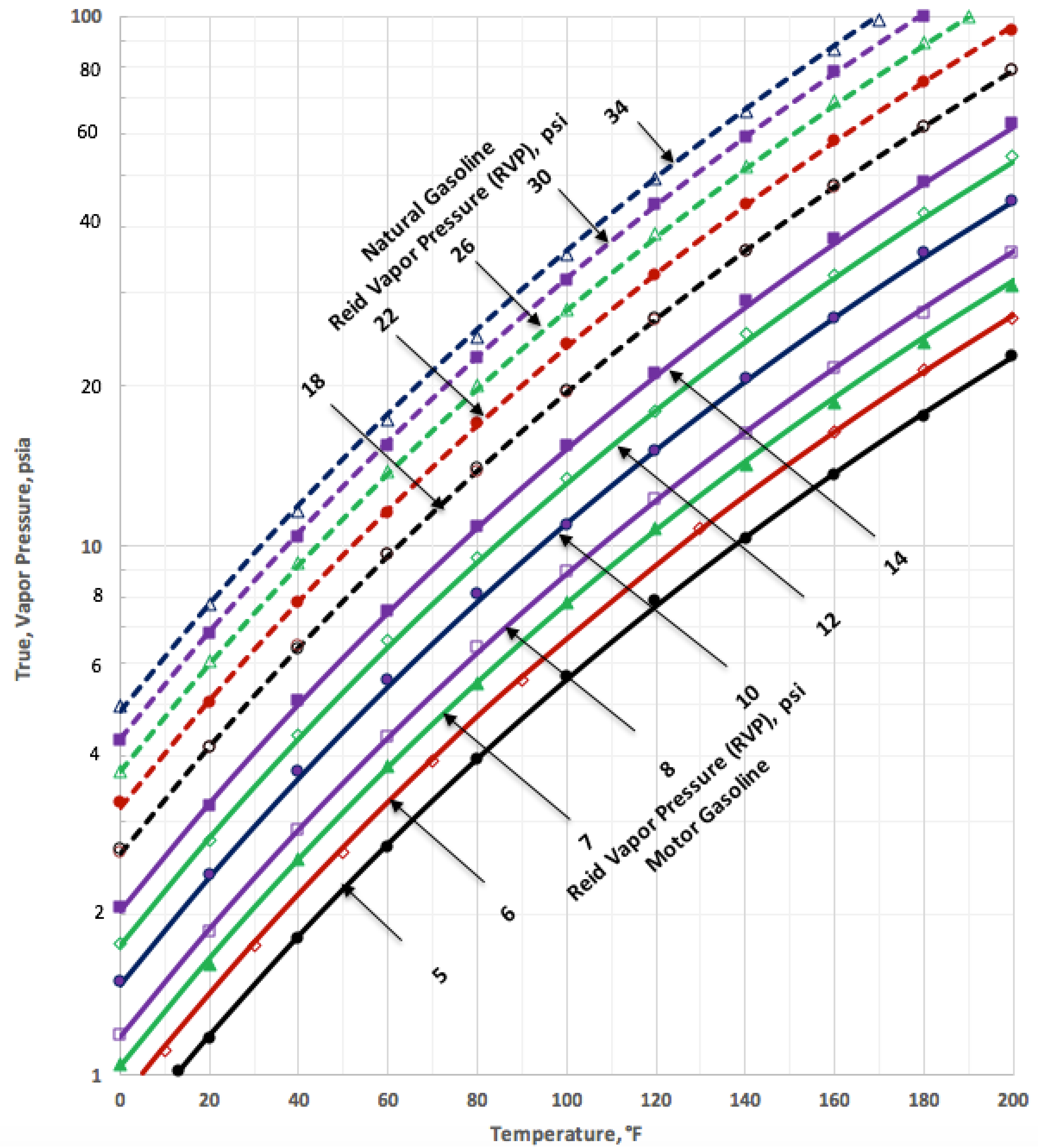

Figure 3. The approximate relationship between RVP and RVP for different volatile crude and petroleum products is given by W L Nelson in reference [2]

2.1.3 CORRELATION BETWEEN VAPOR PRESSURE AND TEMPERATURE OF A FLUID

Clausius – Clapeyron Equation

Clausius-Clapeyron equation is an equation developed to provide us a way to find the heat of vaporization, the energy that must be supplied to vaporize a mole of molecules in the liquid state. As we know the vapor pressure steadily increases as the temperature increases. For that, this [5]Clausius – Clapeyron equation acts as a mathematical model for the pressure increase as a function of temperature. The correlation between the vapor pressure and the temperature is shown in the equation below:-

$$\ln P = \frac{-L}{R}\left(\frac{1}{T}\right) + c$$

Eguation 2. Where ln P is the natural logarithm of the vapor pressure, ΔHvap is the heat of vaporization, R is the universal gas constant (8.31 J·K-1mol-1), T the absolute temperature, and C a constant (not related to heat capacity) [5].

According to the Clausius–Clapeyron relation, the vapor pressure of any substance increases non-linearly with temperature. From the definition, the atmospheric pressure boiling point of a liquid (also known as the normal boiling point) is the temperature at which the vapor pressure equals the ambient atmospheric pressure. With any incremental increase in that temperature, the vapor pressure also increases, hence finally it becomes sufficient to overcome atmospheric pressure and lift the liquid to form vapor bubbles inside the bulk of the substance. For that we can see the bubble formation deeper in the liquid requires a higher temperature due to the higher fluid pressure.

2.1.4 ESTIMATION OF VAPOR PRESSURE USING ANTOINE EQUATION

Antoine equation is the equation used to estimate the vapor pressure at specified temperature. If the normal boiling point (vapor pressure 1 atm) and the critical temperature and pressure are known, then a straight line drawn through these two points on a plot of log pressure versus reciprocal absolute temperature can be used to make a rough estimation of the vapor pressure at intermediate temperatures.

Several equations have been developed to express vapor pressure as a function of temperature. [7]One of the most commonly used is the three-term Antoine equation, as shown below:-

$$\log P = A - \frac{B}{T}$$

Equation 3. Where P is vapor pressure, mmHg, A, B, C is the Antoine coefficients, T is temperature, K [7].

2.2 OFFSHORE

Cendor Phase 2 Field Project is located at the offshore peninsular Malaysia [4]. A number of upstream processing facilities are located there. Therefore, a bit knowledge about oil and gas industry need to be obtained for the ease of doing this thesis. From reference [3], at offshore, there are a number of different structures utilized. The types of structure used depends on some factors such as the size of production, the seabed condition and the seawater water depth. In the last few years, technology has evolved in the industry and we could see pure sea bottom installations has been installed with multiphase piping to shore. For that, no topside facilities need to be installed offshore. However changes take time, and for that the installation offshore definitely is still widely used.

2.2.1 FLOATING PRODUCTION STORAGE AND OFFLOADING (FPSO)

Floating Production, Storage and Offloading (FPSO) is one of the Floating Production installed offshore. Their main advantage is that they are a standalone structure that does not need external infrastructure such as pipelines or storage. Crude oil is offloaded to a shuttle tanker at regular intervals, from days to weeks, depending on production and storage capacity. FPSOs currently produce from around 10,000 to 200,000 barrels per day.[3] An FPSO is typically a tanker type hull or barge, often converted from an existing crude oil tanker (VLCC or ULCC). Due to the increasing sea depth for new fields, they dominate new offshore field development at more than 100 meters water depth. The wellheads or subsea risers from the sea bottom are located on a central or bow-mounted turret, so that the ship can rotate freely to point into wind, waves or current.[3] In today's world, most installations use subsea wells. Like this FPSO Cendor, all the main process is placed on the deck, or as known as topside of the vessel. After the crude oil has been processed and stabilized, they are stored in the hull of the vessel and subsequently offloaded to a shuttle tanker to be transported to the shore. In some cases, pipeline is also used for the transport of the crude oil.

2.3 PRINCIPLE OF SEPARATION PROCESS

More often than not, the well produces a combination of gas, oil and water, with various contaminants that must be separated and processed. Some wells, depending on its location have pure gas production which can be taken directly for gas treatment and/or compression.[3] The production separators come in many forms and designs, with the classic variant being the gravity separator. In gravity separation, the well flow is fed into a horizontal vessel. Reference [1] states that retention period is usually five minutes, allowing gas to bubble out, water to settle at the bottom and oil to be taken out in the middle. The pressure is often reduced in several stages (high pressure separator, low pressure separator, etc.) to allow controlled separation of volatile components. A sudden pressure reduction might allow flash vaporization leading to instability and safety hazards.[3]

2.3.1 SEPARATION PROCESS IN OIL AND GAS

REMOVAL OF GAS FROM OIL

The physical and chemical characteristics of the oil and its conditions of pressure and temperature determine the amount of gas it will contain in solution. The rate at which the gas is liberated from a given oil is a function of change in pressure and temperature. The volume of gas that an oil and gas separator will remove from crude oil is dependent on several factors [8]:-

1) Physical and chemical characteristics of the crude.
2) Operating pressure of the separators.
3) Inlet temperature.
4) Inlet flowrate.

On top of that, agitation, heat, special baffling, coalescing packs, and filtering materials can assist in the removal of gas that otherwise may be retained in the oil because of the viscosity and surface tension of the oil [3]. Gas can be removed from the top of the drum by virtue of being gas. Oil and water are separated by a baffle at the end of the separator, which is set at a height close to the oil-water contact, allowing oil to spill over onto the other side, while trapping water on the near side. The two fluids can then be piped out of the separator from their respective sides of the baffle. The produced water is then either injected back into the oil reservoir, disposed of, or treated [3]. The bulk level (gas–liquid interface) and the oil water interface are determined using instrumentation fixed to the vessel. Valves on the oil and water outlets are controlled to ensure the interfaces are kept at their optimum levels for separation to occur. The separator will only achieve bulk separation. The smaller droplets of water will not settle by gravity and will remain in the oil stream. Normally the oil from the separator is routed to a coalescer to further reduce the water content.

SEPARATION OF WATER FROM OIL

Today oil fields produce greater quantities of water than they produce oil. Along with greater water production are emulsions and dispersions which are more difficult to treat. The separation process becomes linked with a myriad of contaminants as the last drop of oil is being recovered from the reservoir[9]. In some instances it is preferable to separate and to remove water from the well fluid before it flows through pressure reductions, such as those caused by chokes and valves. Such water removal may prevent difficulties that could be caused downstream by the water, such as corrosion which can be referred to as being a chemical reactions that occurs whenever a gas or liquid chemically attacks an exposed metallic surface.[3] Corrosion is usually accelerated by warm temperatures and likewise by the presence of acids and salts. Other factors that affect the removal of water from oil include hydrate formation and the formation of tight emulsion that may be difficult to resolve into oil and water[3]. The water can be separated from the oil in a three-phase separator by use of chemicals and gravity separation[7]. If the three-phase separator is not large enough to separate the water adequately, it can be separated in a free-water knockout vessel installed upstream or downstream of the separators.

2.3.2 EFFECT OF SEPARATOR OPERATING PRESSURE ON LIQUID RECOVERY

Produced fluid from well usually possess more than one component. Due to the multi-component nature of the produced fluid, the amount of liquid that will be obtained in the separator increases with the pressure at which the separation occur. For that liquid will contain some light component that will vaporize in the storage tank downstream of the separator. If the pressure for initial separation is too high, too many light components will stay in the liquid phase at the separator and be lost to the gas phase at the tank condition. This situation would not be economical since wastage of crude oil would occur. In the case of the pressure being too low, there will be very few of these light components to be stabilized into liquid. Hence, at the end of the process they will also be lost as gas[8].

As a matter of fact, the inclination of any one component in the process stream to flash to the vapor phase depends on its partial pressure[10]. From reference[5], the partial pressure of a component in a vessel is defined as the number of molecules of that component in vapor space divided by the total number of molecules of all components in the vapor space times the pressure in the vessel. Thus, if the pressure in the vessel is high, the partial pressure for the component will also relatively be high and the molecules of that component will tend toward the liquid phase[11]. Reference [9], states that as the separator pressure increases, the liquid flow rate out of the separator would also increase.

2.3.2 EFFECT OF NUMBER OF STAGES ON LIQUID RECOVERY

Crude oil is made up of many components of hydrocarbons from C1 to C36. Due to this multicomponent property of this crude oil, we can observe that as the number of stages of separation after the initial separation increases, the portion of light components that will be stabilized into the liquid phase would also increase [12]. In a multistage separation process, the light hydrocarbons that flash off are discharged at reasonably high pressure, keeping the partial pressure of the intermediate hydrocarbons lower at each stage. As the number of stages approach infinity, the lighter molecules are removed as soon as they are formed and the partial pressure of the intermediate components is maximized at each stage. The compressor horsepower required can also be saved by stage separation as some of the gas is captured at a higher pressure during separation process.

Reference [12] states that the higher the number of stages that are added to the process, there will be less in the incremental of liquid recovery. The saving of costs by adding a stage in the separation process should be more than expenditure and the cost of additional separator, piping, controls, space and some of its complexity. Usually, for each facility there is an optimum number of stages and it may be different from well to well.

2.4 PROPERTY PACKAGES

To ensure the accuracy and validity of a simulation, the selection of thermodynamic model plays a very crucial role. With the correct thermodynamic package selected, this will ensure the smoothness of the simulation and accuracy of the simulation result.

Apart from that, the property package also would allow the prediction of the properties of the mixture regardless of the type of components. The table below shows the typical system and its recommended property methods:-

Type of System	Recommended Property Method
TEG Dehydration	PR
Sour Water	PR, Sour PR
Cryogenic Gas Processing	PR, PRSV
Air Separation	PR, PRSV
Atm. Crude Towers	PR, PR Options, GS
Vacuum Towers	PR, PR Options, GS (<10 mmHg), Braun K10, Esso K
Ethylene Towers	Lee Kesler Plocker
High H_2 Systems	PR, ZJ or GS
Reservoir Systems	Steam Package, CS or GS
Hydrate Inhibition	PR
Chemical Systems	Activity Models, PRSV
HF Alkylation	PRSV, NRTL

Figure 4. The typical system and its recommended property methods.[13]

2.4.1 PENG ROBINSON

The Peng–Robinson general equation corresponds to a Redlich–Kwong EOS modification, in order to have a more accurate approximation to the VLE state[14]. Aspen Hysys includes improvements to the original PR with the aim of extending the applicability range and improve the no-ideal system description. It incorporates a wider range of temperature and pressure, starting with cryogenic to high temperatures; and from vacuum pressures to high pressure systems. It offers a complete database for the binary interaction parameter, implying good results for hydrocarbon mixtures[14]. The same EOS predicts the distribution of heavy petroleum components, aqueous glycol and methanol systems[14]. For petrochemical or gas and oil applications, the PR EOS is generally the recommended property package[15]. This EOS can be accurate for a wide range of system conditions. It solves rigorously any single, two-phase or three-phase system with a high degree of efficiency and reliability[15].

2.4.2 CHAO SEADER

CS package uses the CS-RK method for the LVE calculation and the Lee Kesler method for the calculation of Enthalpy and Entropy. Fugacity coefficients in the vapor phase are calculated by means of the 'corresponding-states principle'[14]. Special functions are incorporated for the calculation of fugacity values in the liquid phase. Chao-Seader thermodynamic package must be used for heavy hydrocarbons, with pressure lower than 10342 kPA (1500 psia)[14], and a temperature range of -17.78 to 260°C (0 to 500 F)[14]. It is used for vapor systems. Also, it can be used for three phase flashes but restricted to the use of pure water in the second liquid phase. For example, it is recommended to use the CS for cases in which water vapor or liquid are the main components[14]. This is because the package includes specific correlations that represent the vapor tables in a precise way. The Chao-Seader thermodynamic package is predictive and is developed for hydrocarbon mixtures with light gases (CO_2 or SH_2)[14]. It can be used for crude towers, vacuum towers and ethylene process parts. This model is semi empirical, based on a wide source of hydrocarbon data[16].

CHAPTER 3. METHODOLOGY

3.1 PROJECT RESEARCH

For this thesis to be done, some research about Crude Stabilization process has been made. The research are done by reading journals, articles and also some consultation given by my director. I have also gained some knowledge of this process when I did an internship at a company called MISC Berhad. MISC Berhad is a subsidiary of Malaysian petroleum conglomerate, Petronas. At MISC Berhad, Crude Stabilization process is one of those processes that are done at the company. Since I have had a bit of knowledge in this process, and this is something I want to do in the future, I decided it is the best thing to do a thesis related to this process to further my knowledge in this industry. The design basis of this process produced by MISC Berhad is also obtained to guide through case study in order to finish this thesis.

3.2 BACKGROUND OF CENDOR PHASE 2 FIELD PROJECT

After doing some research and literature review, detailed data of the well need to be obtained. Those data can be obtained in the Design Basis Memorandum provided by MISC Berhad. A request has been made to my former supervisor at MISC Berhad, and an approval has been obtained for me to use the data for my thesis without any conflict of interest.

This thesis uses Cendor Phase 2 FPSO project as reference to be made as a case study. All composition, final requirement of crude oil, and processes are based on this real life project. This Cendor Field is located at offshore Peninsular Malaysia. In 2006, due to its high potential of long term production, an FPSO (Floating, Storage, Production and Offloading vessel) was installed at the field. These installed facilities have proven that the reservoir can be very active in the production of crude oil. There are about 29 wells located at this field, and these wells will be drilled from 2 remote wellhead platforms, one with a high pressure condition, and the other with a low pressure condition. Each wellhead is equipped with capability for water injection, gas lift and oil production. The FPSO will retrieve the crude oil from these wellheads and the Crude Oil Stabilization process is done on the topside of the FPSO.

3.3 PROJECT SIMULATIONS

After a thorough research is done and all data has been obtained, the simulation process is started by using Aspen HYSYS ver. 8.8. The main intention of this simulation is to find the best parameters and operating condition in order to optimize the Cendor Phase 2 FPSO operation and crude oil production by reducing its vapor pressure. The process flow diagram (PFD) was produced using the Aspen HYSYS software and the parameters inside the process will be manipulated as obtain the desired/optimum results. The Gantt diagram for the execution of this thesis is shown below:-

Activity	Week																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Preliminary Research : Understanding the fundamental theories and concept, findings of suitable refernences.	■	■																						
Detailed Research : Consultation with director, data acquirement, familiarization with Aspen HYSYS software.			■	■	■	■																		
Process Simulation : Conduct a simulation using HYSYS and collect the results of the simulation.							■	■	■	■														
Analysis of Result : Analyze the result from the process simulation software (HYSYS) and relate it with the literature reference.									■	■	■	■	■	■	■	■	■	■						
Discussion of Analysis : Discuss the outcome and results obtained and make a conclusion out of the study, determine if the objective has been met.																		■	■	■				
Report Writing : Compilation of all research findings, literature reviews and experimental outcome and work into a final report.																					■	■	■	
Delivery of the project to the Director.																								■

Table 1. Gant Diagram for the execution of the whole studies.

4.1 PROCESS DESCRIPTION

Based on the Process Flow Diagram (PFD) of the topside of FPSO shown in Figure 5, it demonstrates the procedure stream outline of the crude oil stabilization process. The simulation is done using Aspen HYSYS 8.8 (ver. 2011) simulator.

For this Cendor Phase 2 FPSO project, all the crude oil that is to be stabilized come from a reservoir named H15. This reservoir contains 29 different wells and the crude oil is fed to the FPSO through 2 different wellheads with different conditions. Flows from the wellhead platforms enter the Cendor FPSO via production infield flowlines which will be connected to either Low Pressure Separation System or High Pressure Separation System. The determination of whether the crude oil feed would enter the Low Pressure Separation System or the High Pressure Separation System depends on the wellheads' condition such as the back pressure sensitivity. Wells which are more sensitive to back pressure will subject to available capacity in the Low Pressure Separation System. While wells which are insensitive having a high Gas/Oil ratio will be connected to the High Pressure Separation System.

The low pressure feed should be heated before entering the Low Pressure Separation System, to the range of temperature of 70^{o}C. The feed that is going to enter the High Pressure Separation System does not need to be heated to minimize heat load that results from the heating of produced water and to avoid the need for cooling of produced water and produced gas. While the heating of produced water can improve the oil – water separation efficiency, the temperature of produced water must remain moderate to fulfill the environment constraint, which allows it to be discharged overboard. From the Process Flow Diagram, we can see that the crude oil is cooled to 37^{o}C at the heat exchanger so that the temperature fulfill the operating temperature range of High Pressure Production Separation which is 25^{o}C to 45^{o}C. Full Process Flow diagram of this project can be seen below:-

PFD of Topside of FPSO (Crude Stabilization Process)

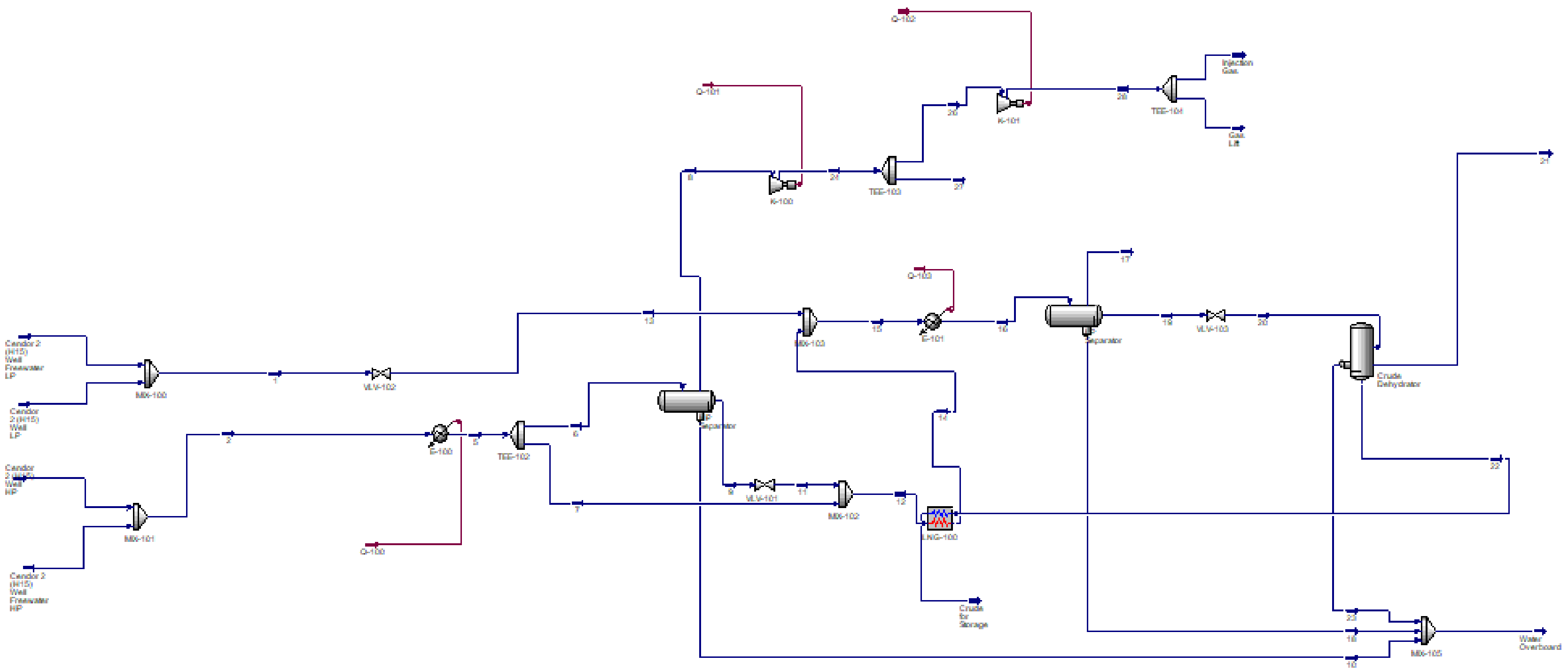

Figure 5. Full PFD of the process.

Design parameters oil & water specification and standard process operating condition are shown below :-

Description	Units	HP Production Separator	LP Production Separator	Degasser
Max Oil	Bpd	35000	35000	35000
Max Gas	MMScfd	75	10	1
Max Water	Bpd	45,000	10,000	1,000
Operating Temp.	^oC	25 - 45	70	70
Max Operating Pressure	Bar	16 – 20	6.0	0.3
Oil in Gas (Max)	Gal/MMScf	0.1	0.1	0.1

Table 2. Design parameters – oil & water specification.[4]

Parameters		Std. Operating Condition	
		Reading	Units
Dry feed volumetric flowrate	High Pressure Well	17500	Barrel/day
	Low Pressure Well	17500	Barrel/day
Free water flowrate	High Pressure Well	1750	Barrel/day
	Low Pressure Well	1750	Barrel/day
Inlet Temperature of Crude Oil	High Pressure Well	140 (60)	F (^oC)
	Low Pressure Well	158 (70)	F (^oC)
Inlet Pressure	High Pressure Well	333.7 (23)	Psia (bar)
	Low Pressure Well	159.7 (11)	Psia (bar)
High Pressure Separator operating pressure		253.82 (17.5)	Psia (bar)
Low Pressure Separator operating pressure		87.04 (6)	Psia (bar)
Degasser operating pressure		4.37 (0.3)	Psia (bar)

Table 3. Standard process operating condition.[4]

After going through the High Pressure Separation System and Low Pressure Separation System, the crude oil has to undergo a degasification process to remove gases from the crude oil in order to avoid bubbles and to separate emulsions into their components. All produced water are discharged overboard.

Produced gases which are the product of the separation process have to be sent to three types of process. One portion of produced gas is sent to Gas Dehydration System, where water is fully removed to produce injection gas and lift gas. These two gases are very crucial in the production of crude oil. These gases are injected inside the well, to replace the void and increase the pressure inside the well, hence making process of sucking out the crude oil from the well easier. The second portion of produced gas is used to make a fuel gas. This gas must undergo a process called CO2 treatment before it can be used as a fuel gas. And last portion of produced gas, which comes from the degasser is liberated through flare.

Lastly after going through all these process, the crude oil now is finally stable and can be stored in tank of the FPSO for transport. The final specifications of the crude oil for this crude stabilization process is shown below :-

Product	Specifications	Operating Target
Export Crude	5 % BS&W	< 0.3 % BS&W
	RVP : 8 psia	
	Temp. : 56 ^{o}C (Max)	

Table 4. Final specifications of the crude oil[4].

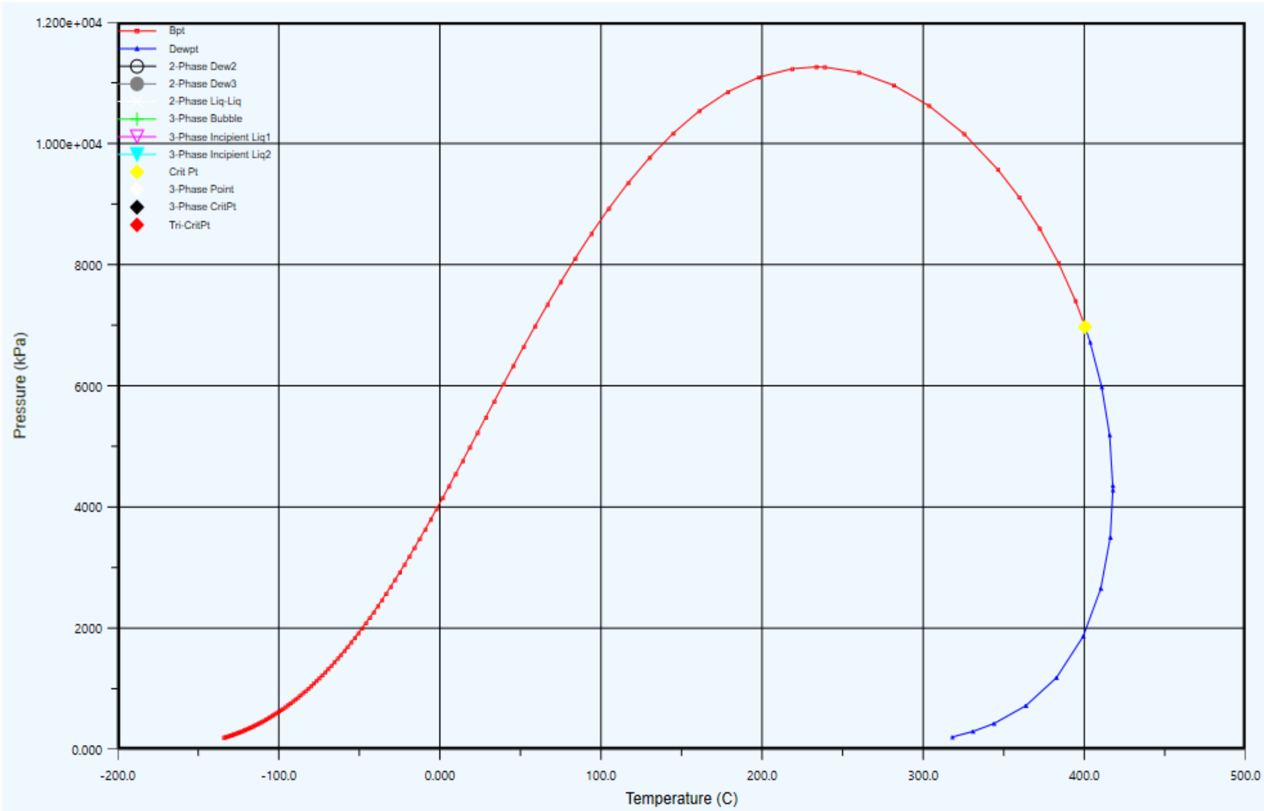

Figure 6. Phase envelope curve for the composition of the feed.

Based on the above phase envelope curve, generated by Aspen HYSYS 8.0, we can observe the bubble points and dew points of the inlet crude at different pressures and temperature as well as the critical point. The critical point is approximately at 400^{o}C and 7000 kPa. As we can see, from the table 3, the temperature and pressure of the crude oil coming from high pressure well is 60 ^{o}C and 2300 kPa respectively. At the same time, the temperature and pressure of the crude oil coming from low pressure well is 70^{o}C and 1100 kPa respectively. From there we can conclude that both crude oil inlet exist as a form of liquid and vapor since both points are located at saturated region.

4.2 PROCESS SIMULATIONS CASE STUDY

In this case study, the simulation is modeled based on Pseudo Component. The specification and composition of feed used in this case study was based on real oil field named Cendor Field Phase 2 which is located in offshore Peninsular Malaysia. Component from C6* to C36+* are joined together to make a new pseudo components. The physical properties for all the pseudo-components are as following :-

Components	Boiling Pt. (^oC)	Molecular Weight (kg/mol)	Density (kg/m3)
C6*	66.90	84.00	685.00
C7*	94.80	96.00	722.00
C8*	118.00	107.00	745.00
C9*	144.90	121.00	764.00
C10*	168.30	134.00	778.00
C11*	185.80	147.00	789.00
C12*	201.90	161.00	800.00
C13*	216.40	175.00	811.00
C14*	231.80	190.00	822.00
C15*	252.00	206.00	832.00
C16*	270.80	222.00	839.00
C17*	287.80	237.00	847.00
C18*	302.90	251.00	852.00
C19*	315.40	263.00	857.00
C20*	327.70	275.00	862.00
C21*	343.30	291.00	867.00
C22*	356.70	306.00	872.00
C23*	368.90	318.00	877.00
C24*	380.80	331.00	881.00
C25*	393.20	345.00	885.00
C26*	405.40	359.00	889.00
C27*	418.20	374.00	893.00
C28*	429.80	388.00	896.00
C29*	441.20	402.00	899.00
C30*	453.40	426.00	902.00
C31*	463.80	430.00	906.00

C32*	474.80	444.00	909.00
C33*	485.70	458.00	912.00
C34*	496.20	472.00	914.00
C35*	506.90	486.00	917.00
1-C36*	526.70	513.00	921.00
2-36*	527.70	514.00	933.00

Table 5. Properties of Pseudo Components.

Components	Tc (°C)	Pc (kPa)	Vc (m3/kgmole)
C6*	234.600	2947	0.368
C7*	270.700	2822	0.406
C8*	298.200	2700	0.441
C9*	327.900	2478	0.497
C10*	352.800	2291	0.550
C11*	371.400	2174	0.589
C12*	388.600	2080	0.626
C13*	404.200	2007	0.659
C14*	419.800	1929	0.695
C15*	437.100	1817	0.745
C16*	452.500	1716	0.795
C17*	473.000	1667	0.836
C18*	486.500	1566	0.897
C19*	498.000	1490	0.949
C20*	509.000	1420	1.002
C21*	522.600	1331	1.075
C22*	534.400	1262	1.139
C23*	545.200	1205	1.197
C24*	555.300	1151	1.258
C25*	565.800	1096	1.323
C26*	576.100	1047	1.388
C27*	586.600	999	1.457
C28*	596.300	957	1.522
C29*	605.600	919	1.585
C30*	614.800	884	1.646
C31*	624.400	855	1.702
C32*	633.400	827	1.758
C33*	642.300	802	1.810
C34*	650.800	779	1.860
C35*	659.600	759	1.904

1-C36*	675.700	727	1.978
2-C36*	661.100	652	2.037

Table 6. Physical Properties of Pseudo Components.

Notes:

1) Water stream are added as a different stream with inlet crude stream (dry basis mole fraction) ranging about 10% of the inlet crude flow.

4.2.1 FLUID PACKAGE

In this case study, two fluid packages have been used. The two property packages used for this case study are:-

a) Peng Robinson
b) Chao – Seader

The main purpose of using these two fluid packages is to compare the final calculations of those two property packages. Since Peng Robinson is a proven property package and already widely used in oil and gas industry, it is very interesting to compare it with another fluid package and prove its reliability for the calculation. Furthermore, this is also one way to produce a highly accurate reading as one fluid package can act as a validation for the other.

4.3 UNITS

In this simulation study, oilfield unit is used in most part of it. Table below shows the conversion of oilfield unit to SI unit.

Measurement	Oilfield Unit	SI Unit	Conversion
Pressure	psi	Pa	6.9×10^3
Rate (oil)	b/d	m^3/s	1.84×10^{-6}
Rate (gas)	Mscf/d	m^3/s	3.28×10^{-4}
Temperature	°C	F	(X°C × 9/5) + 32

Table 7. Conversion from Oilfield unit to SI Unit.

4.3. EFFECTS OF DIFFERENT OPERATING CONDITIONS ON TRUE VAPOR PRESSURE (TVP) AND REID VAPOR PRESSURE (RVP)

In the upstream, where the crude oil stabilization is done, the process does not always run ideally at a steady state. This is due to the fact that fluctuations always occur in the process parameter. The process parameter such as temperature, pressure of the well really do change from time to time. This is caused by some reasons such as changing surrounding conditions, tides level, upset in other related process unit upstream and breakdown of related operating unit. Therefore, as an engineer, this change of condition must be studied and not taken for granted so that some measures can be taken to ensure that crude oil can always be produced at an optimum level. For that fact, it is crucial for the engineers to have the knowledge of how much of these changes that the process can tolerate and at which point the parameter change will cause the product to become off-specification. In order to obtain the knowledge, a study is done on the simulated crude oil stabilization of Cendor Phase 2 Field by varying all the parameters below:

1. Inlet Feed Parameters

a. Dry feed volumetric flowrate

b. Free water flowrate

c. Inlet Temperature

d. Inlet Pressure

2. Three Phase Separator Parameters

a. High Pressure Separator operating pressure.

b. Low Pressure Separator operating pressure.

c. Degasser operating pressure.

3. Compositional Analysis.

a. Analysis of composition of crude oil at High Pressure Separator.

b. Analysis of composition of crude oil at Low Pressure Separator.

c. Analysis of composition of crude oil at Degasser.

True Vapor Pressure, TVP and Reid Vapor Pressure, RVP

In oil and gas industry, in order to determine whether the crude oil is safe to be transported and further process, the specifications that is taken into account for a crude stabilization plant is the True Vapor Pressure, TVP and the Reid Vapor Pressure, RVP of the stabilized crude. Some client uses RVP as the indicator of the vapor pressure of the crude and some, uses RVP as their indicator for the product. Therefore, the TVP and RVP of the product is the most important specification that needs to be controlled during the process of the crude stabilization plant to fulfill the clients' specifications. The lower the final TVP and RVP of the product, the more stable it is, and the higher the quality the stabilized oil possesses. As stated earlier, in this study, the effect of parameter changes on the TVP and RVP has been studied by varying all manipulated parameters, such as inlet feed properties, three phase separator system. Any evident impacts of the variables on the operation will be studied. And at the end of the study, the compositional analysis of the crude oil will be done to see its impact towards the RVP and TVP of the crude oil.

4.3.1 EFFECTS OF INLET FEED PARAMETERS

In this simulation, the crude oil fedd properties are manipulated to study the effects of the inlet parameters towards crude oil stabilization process. Standard incoming crude inlet to the terminal is at 35 Kbd at 140 F (60 °C) for the crude coming from Cendor (H15) High Pressure Well (HP), and 158 (70 °C) for the crude coming from Cendor (H15) Low Pressure Well (LP). The pressure at Cendor (H15) High Pressure Well (HP) and Cendor (H15) Low Pressure Well (LP) is 333.7 psia (23 bar) and 159.7 psia (11 bar) respectively, with BS&W of 5 vol%. The inlet properties such as flow rate, temperature, pressure and free water content are set as the variable being manipulated. Whereas True Vapor Pressure, TVP and Reid Vapor Pressure, RVP of the stabilized crude, act as the parameters that we want to control. Table below shows the status of operating condition for every change of parameter;-

Parameters		Dry feed volumetric flowrate		Free water flowrate		Inlet Temperature		Inlet Pressure		HPS	LPS	Degasser
		HP Well	LP Well	HP Well	LP Well	HP Well	LP Well	HP Well	LP Well			
Dry feed volumetric flowrate	High Pressure Well	M	C	C	C	C	C	C	C	C	C	C
	Low Pressure Well	C	M	C	C	C	C	C	C	C	C	C
Free water flowrate	High Pressure Well	C	C	M	C	C	C	C	C	C	C	C
	Low Pressure Well	C	C	C	M	C	C	C	C	C	C	C
Inlet Temperature	High Pressure Well	C	C	C	C	M	C	C	C	C	C	C
	Low Pressure Well	C	C	C	C	C	M	C	C	C	C	C
Inlet Pressure	High Pressure Well	C	C	C	C	C	C	M	C	C	C	C
	Low Pressure Well	C	C	C	C	C	C	C	M	C	C	C
High Pressure Separator operating pressure		C	C	C	C	C	C	C	C	M	C	C
Low Pressure Separator operating pressure		C	C	C	C	C	C	C	C	C	M	C
Degasser operating pressure		C	C	C	C	C	C	C	C	C	C	M

Table 8. Status of Operating condition for every change of parameter.

Notes:

1) M stands for Manipulated Variables, and C stands for Constants.
2) The duty of the separators and heat exchangers are kept constant throughout the simulation.

a. DRY FEED VOLUMETRIC FLOWRATE

Manipulated Variables: Std. Ideal Liquid Flow (barrel/day)

Feed: Cendor 2 (H15) Well HP

Fluid Package: Peng Robinson

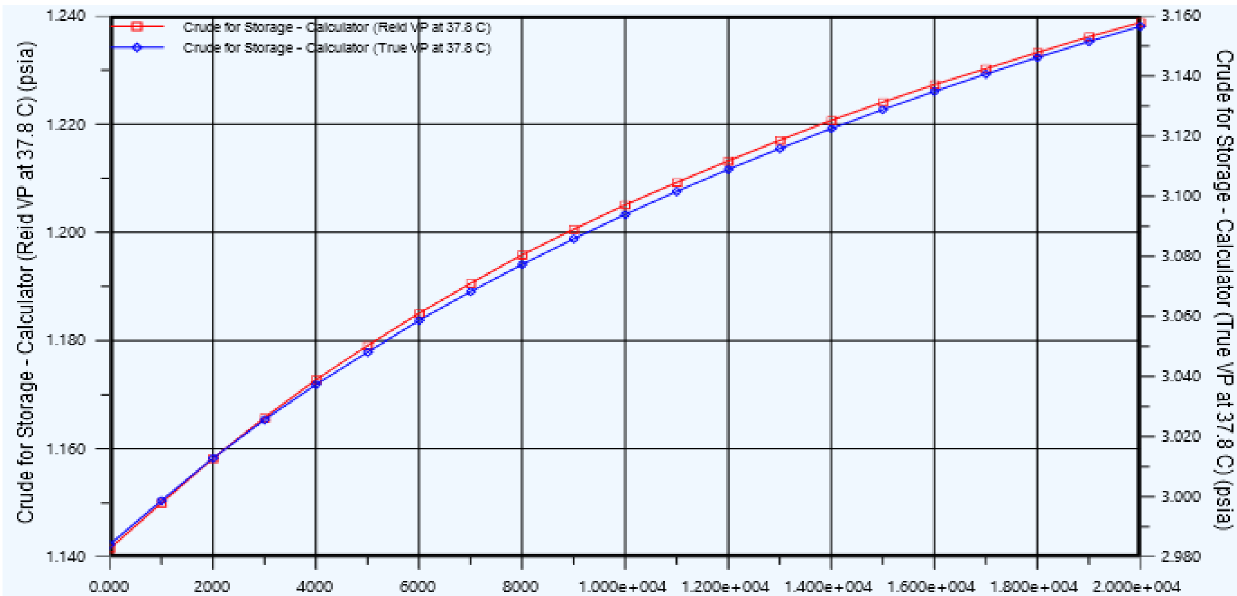

Figure 7. Cendor 2 (H15) Well HP - Std Ideal Liq Vol Flow (barrel/day) using Peng Robinson

Fluid Package: Chao – Seader

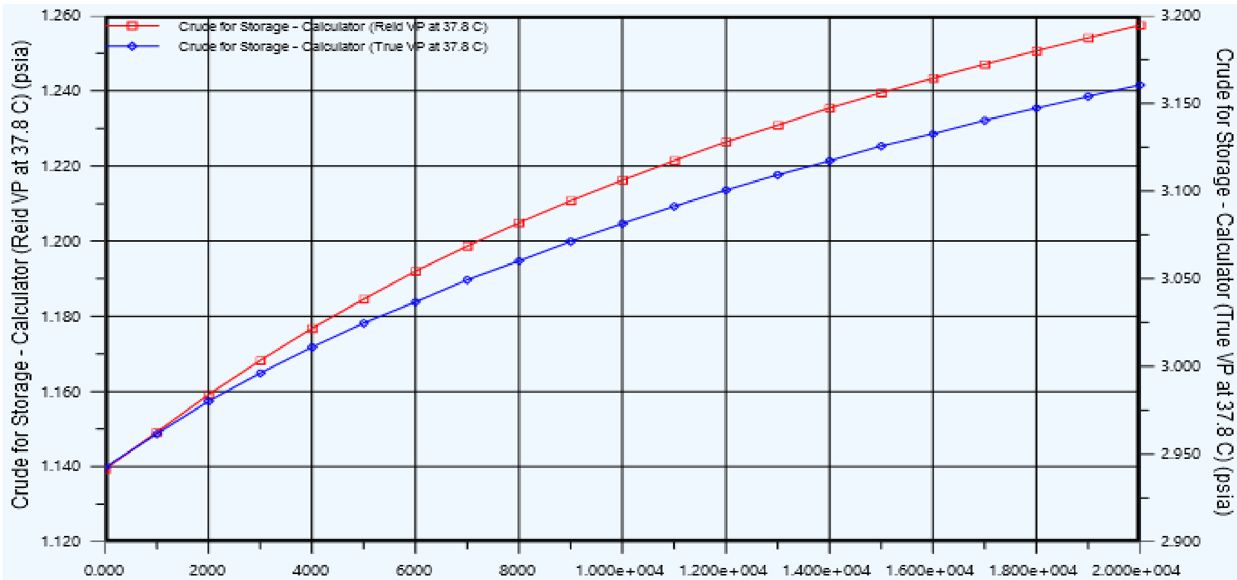

Figure 8. Cendor 2 (H15) Well HP - Std Ideal Liq Flow (barrel/day) using Chao - Seader

In this study, the standard feed flow rate used for the base case is 35 kBD, which 17.5kBD is coming from Cendor (H15) High Pressure Well (HP), and 17.5 kBD coming from Cendor (H15) Low Pressure Well (LP). The flow rate is then decreased to 0 and then increased to 20 kBD with 1kBD interval. The total number of states for this study is 21. From the graphs above, it can be observed, as the flow rate coming from Cendor (H15) High Pressure Well (HP) increases, the final reading of True Vapor Pressure (TVP) and Reid Vapor Pressure (RVP) also increase. This increase in the final TVP and RVP is because as the flow rate increases, more duty is required to flash off the light component of the crude oil. When simulating the effects of the feed flow rate, all other variables and unit operation such as heat exchangers duty are kept constant. This results in insufficient amount of heat to flash off the entire volatile component leaving huge amount of light components in the stabilized crude, thus increasing total mixture's final TVP and RVP. In addition, as we look at the path taken by the crude oil from High Pressure Well in the PFD, more portion of the crude oil have to go through high pressure separator, hence resulting to more portion of it to experience lower pressure loss. Lower pressure loss means less light components being flashed off, hence higher value of TVP and RVP. Therefore, the TVP and RVP would gradually increase with the increase of feed flow rate from Cendor (H15) High Pressure Well (HP).

Feed: Cendor 2 (H15) Well LP

Fluid Package: Peng Robinson

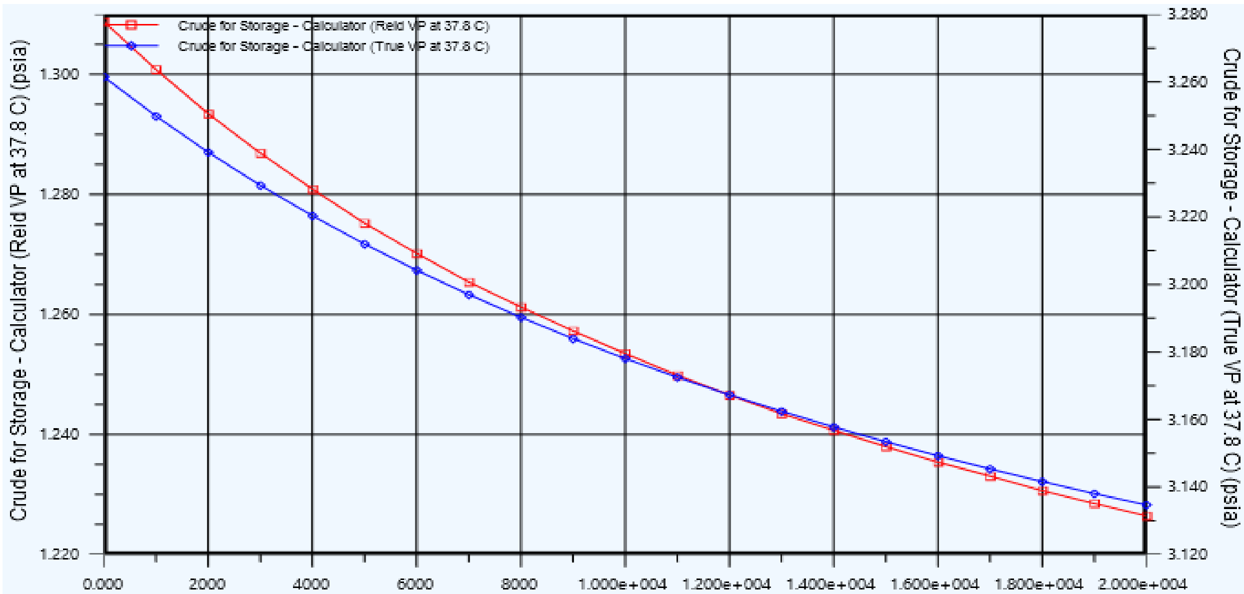

Figure 9.Cendor 2 (H15) Well LP - Std Ideal Liq Flow (barrel/day) using Peng Robinson

Fluid Package: Chao – Seader

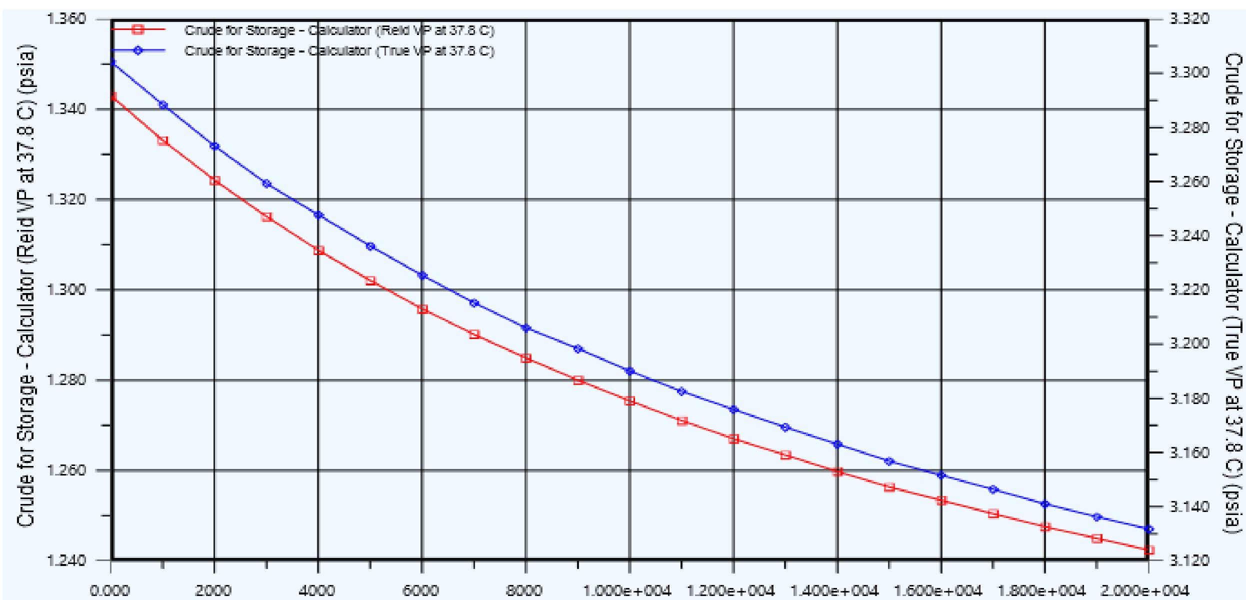

Figure 10.Cendor 2 (H15) Well LP - Std Ideal Liq Flow (barrel/day) using Chao – Seader

However, in this case of crude oil coming from Cendor (H15) Low Pressure Well (LP), the result seems to be in contrary with the one coming from Cendor (H15) High Pressure Well (HP). From the graphs, it can be seen as the flow rate increases, the TVP and RVP decrease. This decrease in TVP and RVP is due to the path taken by the crude oil in this crude oil stabilization process. As we can see from the Process Flow Diagram (PFD), the crude oil coming from the low pressure well does not have to go through the High Pressure Separator, in fact they go through straight away to the Low Pressure Separator. Therefore, since the crude oil goes through straight away to the Low Pressure Separator, the pressure loss is higher than the crude oil coming from Cendor (H15) High Pressure Well (HP) since they have to go through the high pressure separator. That means, with higher flow rate coming from the Cendor (H15) Low Pressure Well (LP), more portions of the crude oil having to experience bigger pressure loss, resulting to more light components being flashed off. The higher the amount of component being flashed off, the lower the TVP and RVP would be. In order to simulate the effects of the feed flow rate coming from low pressure well, all other variables and unit operation such as heat exchangers duty, feed flowrate coming from the Cendor (H15) High Pressure Well (HP) are kept constant.

In this case, the effect of the path taken by the crude oil in the process override the effect of insufficient duty from the heat exchanger. Therefore, the TVP and RVP would gradually decrease with the increase of feed flow rate from Cendor (H15) Low Pressure Well (LP).

b. Free water flowrate

Feed: Cendor 2 (H15) Well Freewater HP

Fluid Package: Peng Robinson

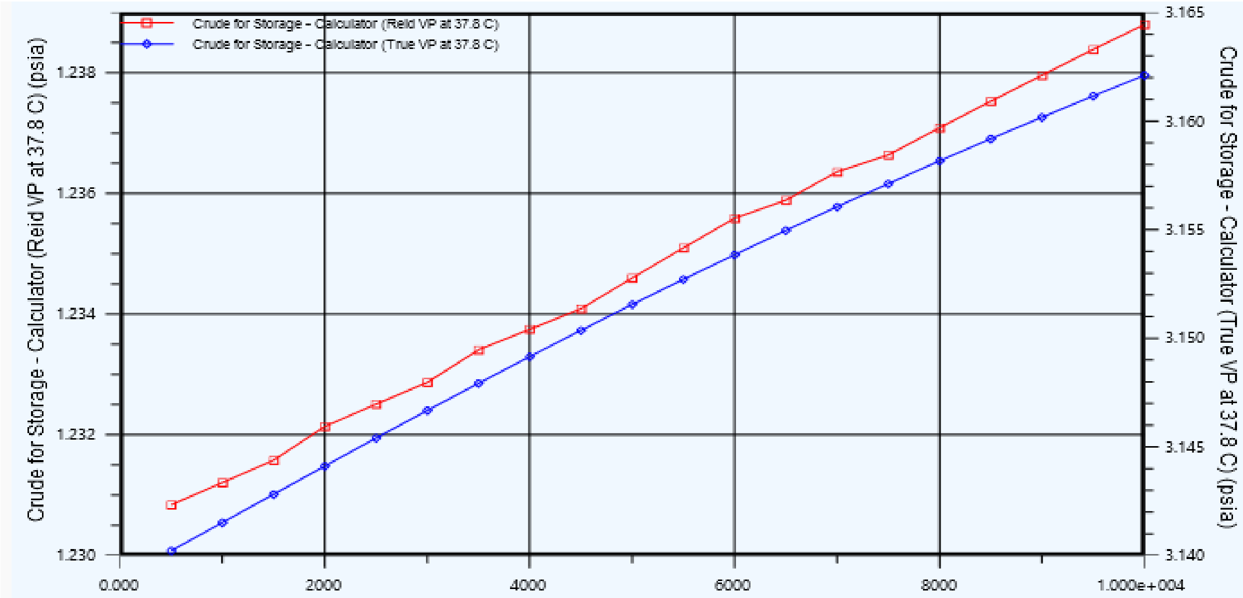

Figure 11. Cendor 2 (H15) Well Freewater HP - Std Ideal Liq Flow (barrel/day) using Peng Robinson

Fluid Package: Chao – Seader

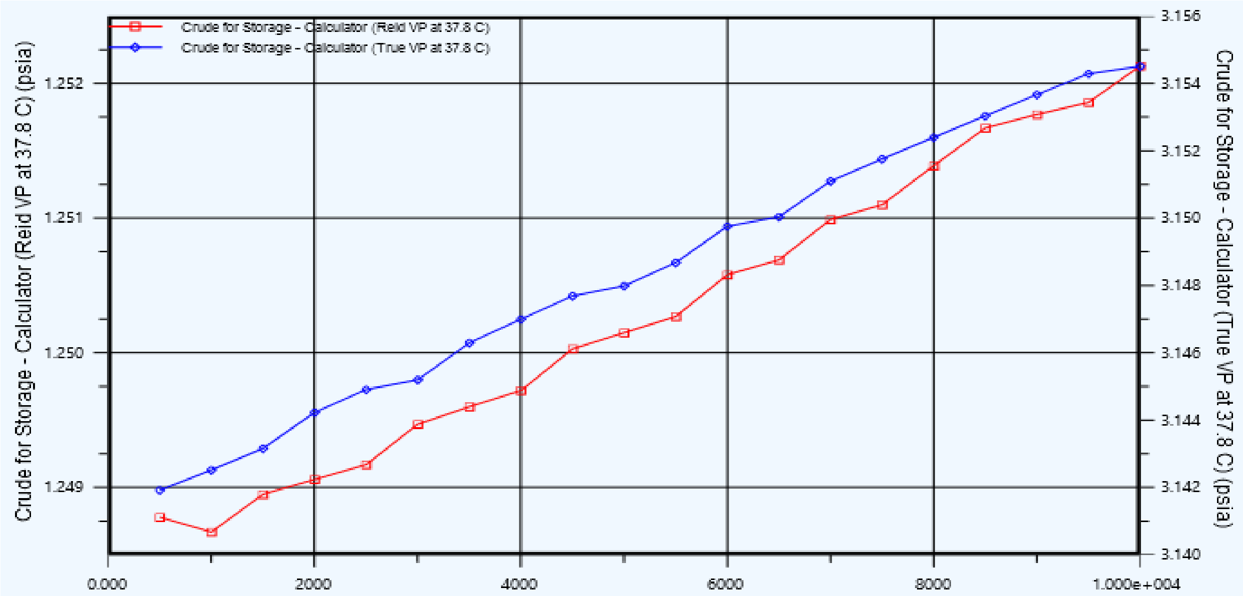

Figure 12.Cendor 2 (H15) Well Freewater HP - Std Ideal Liq Flow (barrel/day) using Chao – Seader

Based on the Cendor Phase 2 Development Project Design Basis Memorandum, the existing facility is capable of processing 10% of free water content in the inlet crude.

As the standard crude oil production is around 35 kBD. Thus the free water content which is assumed to be 10% of the dry feed is about 3.5 kBD, 1.75 kBD from each wellhead. When studying the effects of water inlet flowrate towards the crude stabilization operation, water flow rate is decreased to 1 kBD and increased to a maximum of 10 kBD with interval of 500 BD. The total number of states of this study is 20. Figure above shows the effects of the water inlet flow rate towards the product TVP and RVP.

From the graph above, as the free water content inside the crude oil coming from Cendor (H15) High Pressure Well (HP) increases, the final stabilized crude oil TVP and RVP would also increase. The increase of free water content would require a higher duty of heat exchangers to heat the process fluid to a suitable temperature before entering the separator. If optimum operating temperature cannot be achieved due to lack of duty being provided, it will affect the separation process in the separator hence, would result in less volatile component being flashed off. Eventually, the final vapor pressure would increase. Besides that, the increase in the water content inside the crude oil coming from Cendor (H15) High Pressure Well (HP) also signifies that more portion of water having to go through high pressure separator, resulting to more portion experiencing lower pressure loss. Lower pressure loss means less light components being flashed off, hence higher value of TVP and RVP.

Therefore, the TVP and RVP would gradually increase with the increase of feed flow rate of free water from Cendor (H15) High Pressure Well (HP).

Feed: Cendor 2 (H15) Well Freewater LP

Fluid Package: Peng Robinson

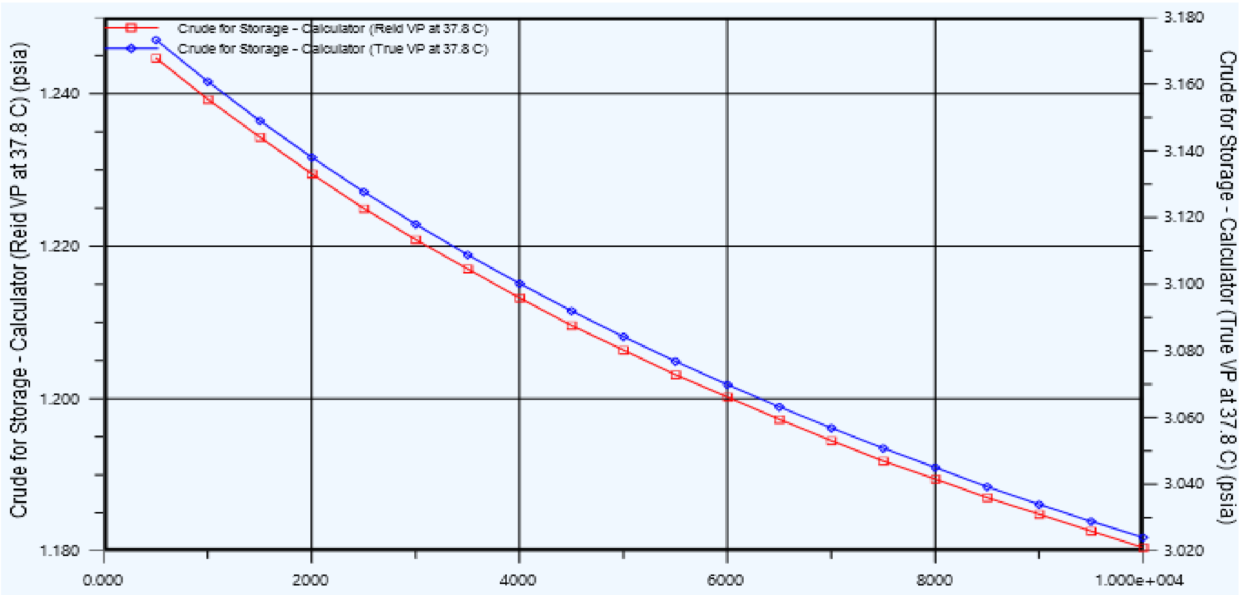

Figure 13. Cendor 2 (H15) Well Freewater LP - Std Ideal Liq Flow (barrel/day) using Peng Robinson

Fluid Package: Chao – Seader

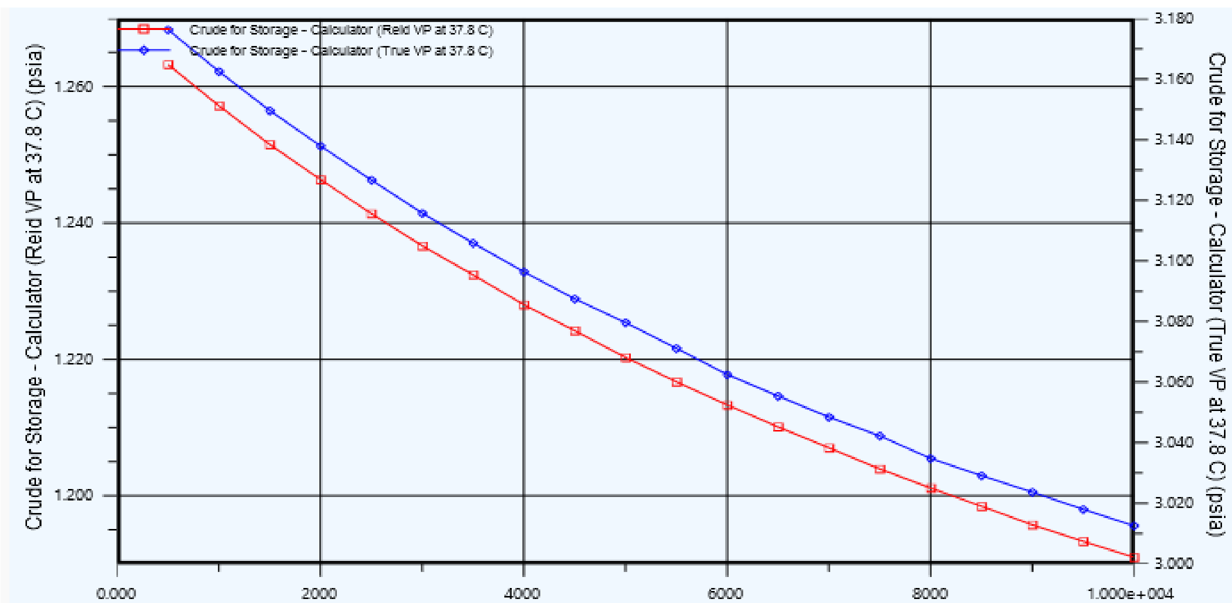

Figure 14. Cendor 2 (H15) Well Freewater LP - Std Ideal Liq Flow (barrel/day) using Chao – Seader.

In order to study the effects of water inlet flowrate towards the crude stabilization operation, free water flow rate is decreased to 1 kBD and increased to a maximum of 10 kBD with interval of 500 BD. The total number of states of this study is 20. Figure above shows the effects of the water inlet flow rate towards the product TVP and RVP.

In this case of free water coming from Cendor (H15) Low Pressure Well (LP), however, the result seems to be in contrary with the one coming from Cendor (H15) High Pressure Well (HP). From the graphs, it can be seen as the flow rate of free water increases, the TVP and RVP decrease. This decrease in TVP and RVP is due to the path taken by the water in this crude oil stabilization process. The water coming from Cendor (H15) Low Pressure Well (LP) does not have to go through the High Pressure Separator, in fact they go through straight away to the Low Pressure Separator. Therefore, since the free water crude oil goes through straight away to the Low Pressure Separator, the pressure loss is higher than the water coming from Cendor (H15) High Pressure Well (HP) since they have to go through the high pressure separator. That means, with higher flow rate of free coming from the Cendor (H15) Low Pressure Well (LP), more portions of the crude oil having to experience bigger pressure loss, resulting to more light components being flashed off. The higher the amount of component being flashed off, the lower the TVP and RVP would be. In order to simulate the effects of the feed flow rate coming from low pressure well, all other variables and unit operation such as heat exchangers duty, feed flowrate coming from the Cendor (H15) High Pressure Well (HP) are kept constant.

Therefore, the TVP and RVP would gradually decrease with the increase of feed flow rate of free water from Cendor (H15) Low Pressure Well (LP).

c. Inlet Temperature

Manipulated Variables: Temperature

Feed: Cendor 2 (H15) Well HP

Fluid Package: Peng Robinson

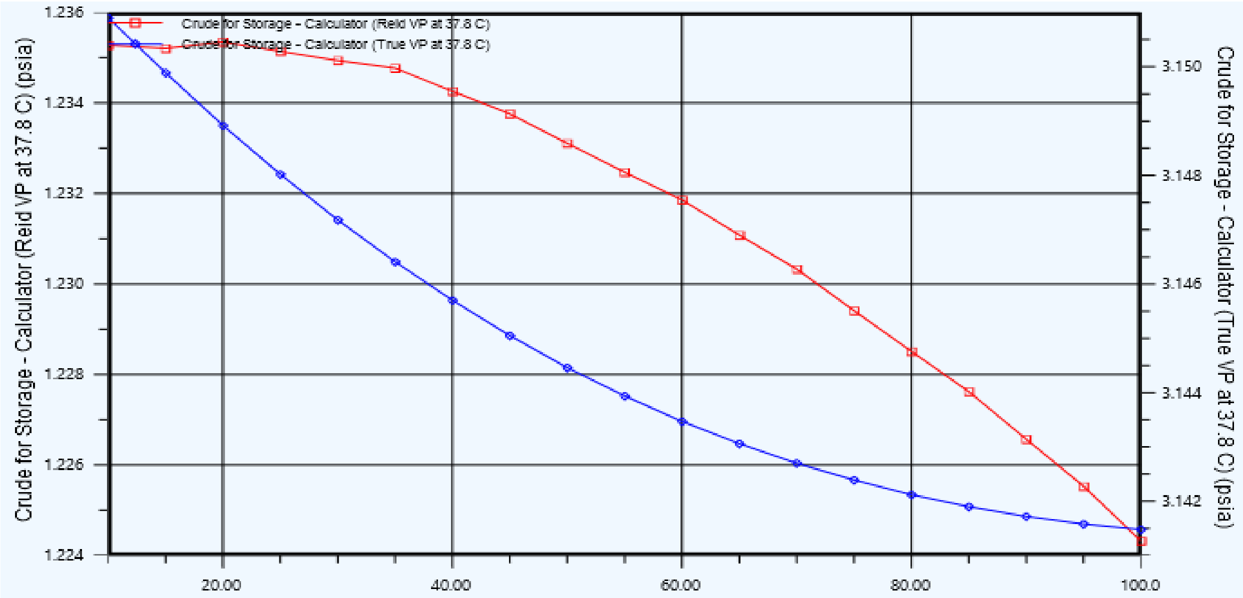

Figure 15. Cendor 2 (H15) Well HP - Temperature (ºC) using Peng Robinson

Fluid Package: Chao – Seader

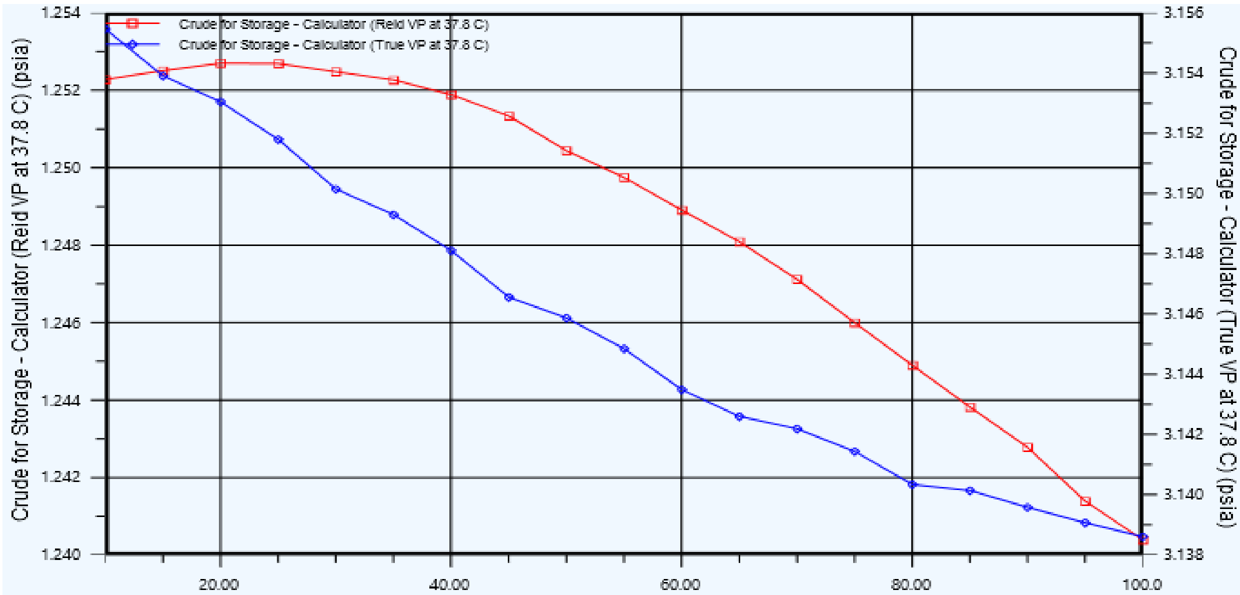

Figure 16.Cendor 2 (H15) Well HP - Temperature (°C) using Chao – Seader

The temperature of inlet feed coming from Cendor Phase 2 Field wellhead is normally between 140F to 176F (60°C to 80°C) depending on the production wellhead condition given in Design Basis Memorandum. For the standard case, the inlet temperature is assumed to be 158 °F (70°C). In order to study the effects of feed temperature towards product TVP and RVP, the temperature is decreased to 0°C and then increased to 100 °C at 5 °C intervals. The total number of states of this study is 19. Figure above shows how the change in feed temperature affects the TVP and RVP of the stabilized crude. As we can observe from the graphs, as the temperature of the feed from Cendor (H15) High Pressure Well (HP) increases, the product final TVP and RVP generally decrease. Even though from the graph using Chao Seader property package, it seems as if the final stabilized RVP of the crude oil increases from the temperature of 10°C to 20°C. This does not happen in the calculation using Peng – Robinson as the property package. This may be due to the complication of the calculation, and generally the pattern are the same for both property package nevertheless, hence it can be neglected. The increase in the feed temperature means the crude oil is closer to the bubble point, and therefore more portion of light components can be flashed off easily.

Feed: Cendor 2 (H15) Well LP

Fluid Package: Peng Robinson

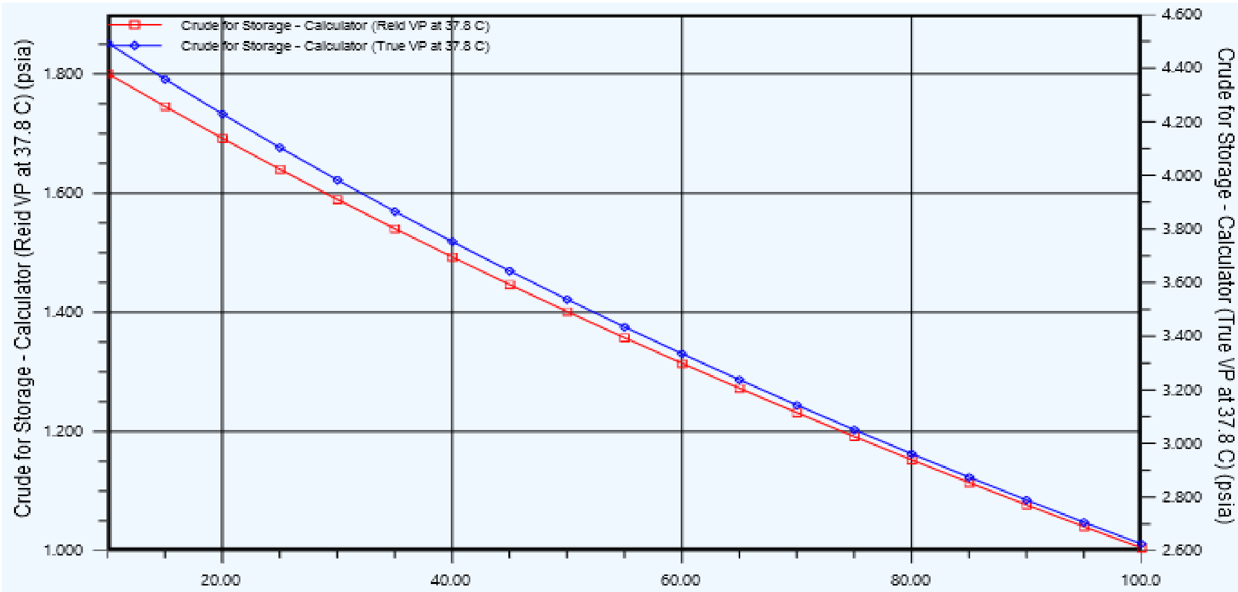

Figure 17. Cendor 2 (H15) Well LP - Temperature (ºC) using Peng Robinson

Fluid Package: Chao – Seader

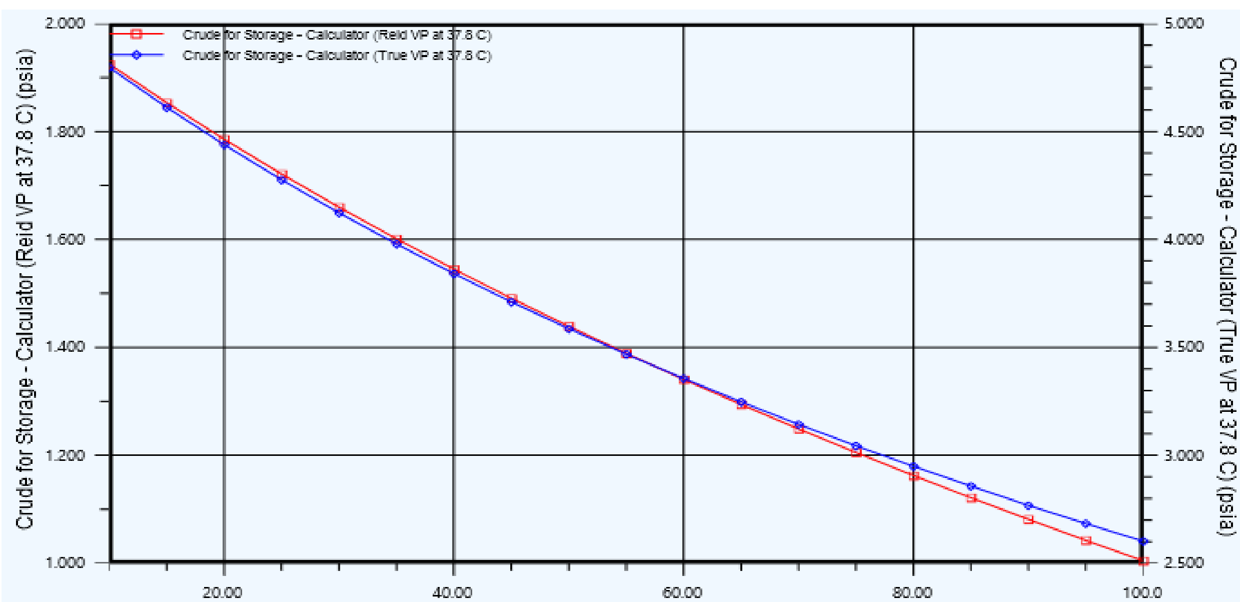

Figure 18. Cendor 2 (H15) Well LP - Temperature (ºC) using Chao - Seader

For the Cendor 2 Low Pressure well, the inlet temperature is assumed to be 140 ^oF (60 ^oC). In order to study the effects of feed coming from Cendor (H15) Low Pressure Well (LP) temperature towards product TVP and RVP, the temperature is decreased to 10^oC and then increased to 100 ^oC at 5 ^oC intervals. The total number of states of this study is 19. Figure above shows how the change in feed temperature affects the TVP and RVP of the stabilized crude.

As we can observe from the graphs, same as the study done at Cendor (H15) High Pressure Well (HP), as the temperature of the feed increases, the product final TVP and RVP gradually decrease. The increase in the feed temperature would cause more portions of the light component to flash off easily from the crude and thus reduce the TVP and RVP of the product.

d. Inlet Pressure

Manipulated Variables: Pressure (Psia)

Feed: Cendor 2 (H15) Well HP

Fluid Package: Peng Robinson

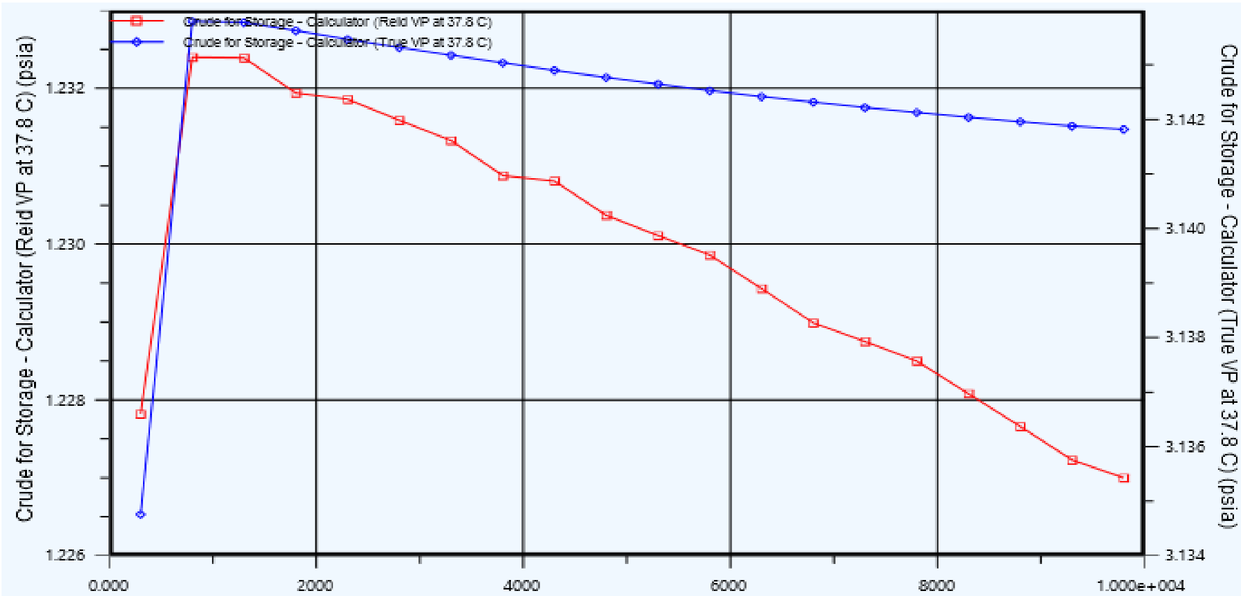

Figure 19. Cendor 2 (H15) Well HP - Pressure (Psia) using Peng Robinson

Fluid Package: Chao – Seader

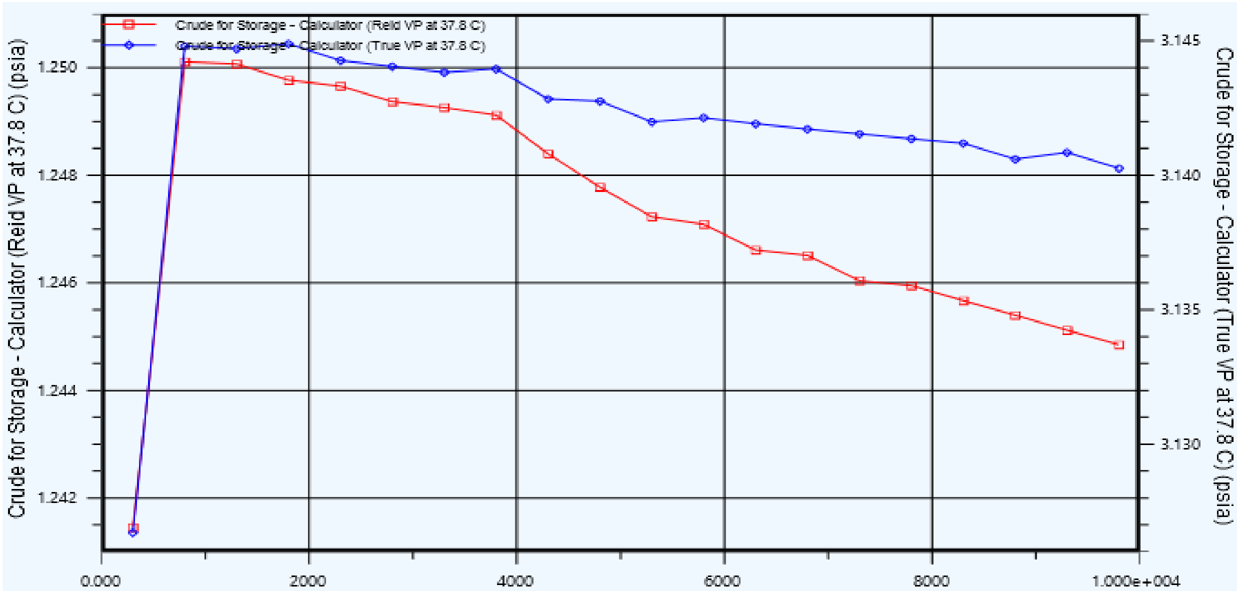

Figure 20. Cendor 2 (H15) Well HP - Pressure (Psia) using Chao - Seader

Based on the Cendor Phase 2 Development Project Design Basis Memorandum, at standard operating conditions, the pressure of the feed to the crude stabilization plant is 33.7 psia (22 bar) at high pressure well and 159.7 psia (10 bar) at low pressure well. First of all, to study the effects of the feed from Cendor (H15) High Pressure Well (HP), pressure towards the product TVP and RVP, the feed pressure is reduced to 300 psia and then increased to 9800 psia at 500 psia intervals. The total number of states of this study is 20. Figure above shows how the change in feed pressure affects the final TVP and RVP of the stabilized crude. Based on the graph, it can be observed that the highest TVP and RVP recorded (3.12 psia and 1.224 psia) is at 800 psia feed pressure. As the pressure of feed increases, the final TVP and RVP of the stabilized crude gradually decreases. This fact is due to the high pressure drop into the pressure vessels which lead to high amount of volatile component being flashed off to the stabilization gas header. The higher the pressure of the inlet the higher the pressure drop. Therefore, the stabilized crude oil would only contain crude oil with less volatile component which has lower TVP and RVP. Due to that fact they can be stored at atmospheric condition safely and wastage of the crude oil can be avoided. From the graph it also shows that the impact of the feed pressure towards the crude stabilization unit is insignificant.

Feed: Cendor 2 (H15) Well LP

Fluid Package: Peng Robinson

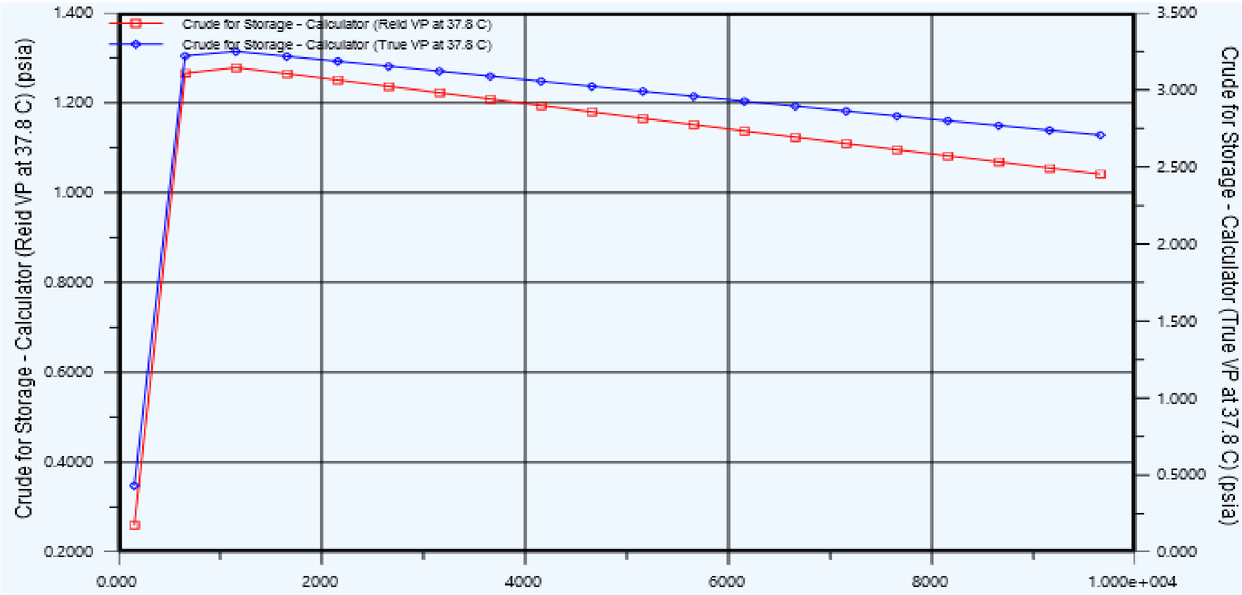

Figure 21.Cendor 2 (H15) Well LP - Pressure (Psia) using Peng Robinson

Fluid Package: Chao – Seader

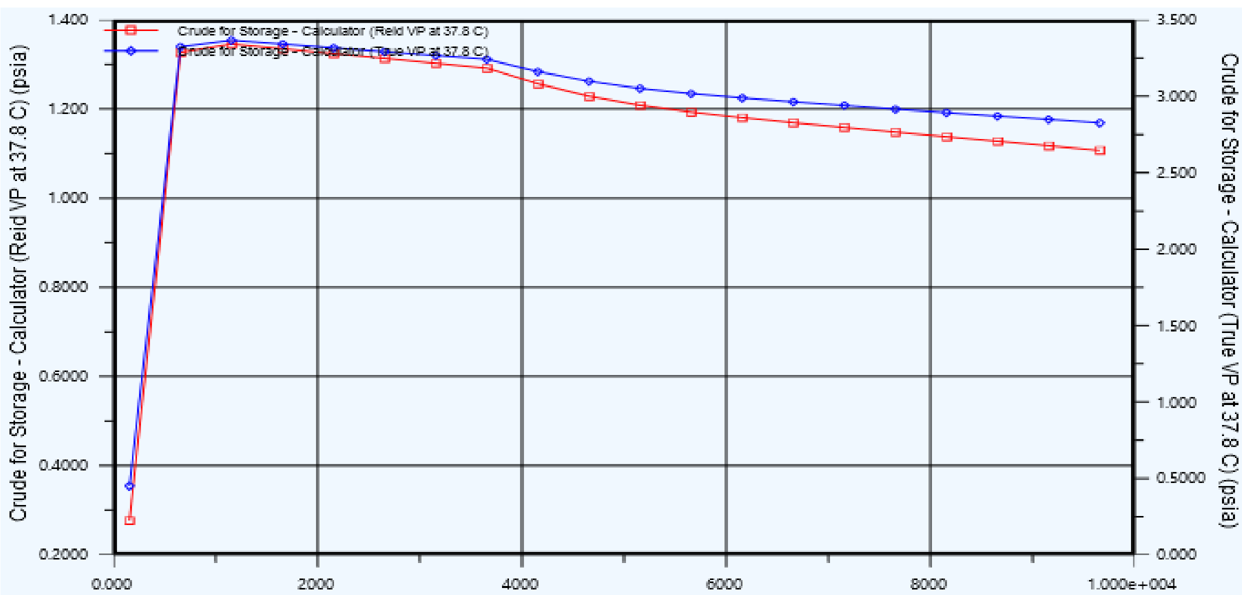

Figure 22. Cendor 2 (H15) Well LP - Pressure (Psia) using Chao - Seader

At Cendor (H15) Low Pressure Well (LP), the pressure is 159.7 psia. Like the previous case, at first, to study the effects of the feed from Cendor (H15) Low Pressure Well (LP), pressure towards the product final TVP and RVP, the feed pressure is reduced to 156 psia and then increased to 9656 psia at 500 psia intervals. The total number of states of this study is 20. The reason why 156 psia is taken as lower bound value is because below the value, the pressure loss in the Degasser would be negative and because of that, there will be a presence of failed state in the simulation. Figure above shows how the change in feed pressure affects the TVP and RVP of the stabilized crude.

Form the graph, it can be seen that the highest final TVP and RVP recorded (3.25 psia and 1.28 psia) is at 1156 psia feed pressure. As the pressure of feed increases, the TVP and RVP of the stabilized crude gradually decreases. This fact is due to the high pressure drop into the pressure vessels which lead to high amount of volatile component being flashed off to the stabilization gas header. The higher the pressure of the inlet, the higher the pressure differential, hence the higher the pressure drop. Therefore, the stabilized crude oil would only contain crude oil with less volatile component which has lower final TVP and RVP. Due to that fact, they can be stored at atmospheric condition safely and wastage of the crude oil can be avoided.

As we can observe, the path taken by the crude oils does not give any difference in the pattern of the vapor pressure with the manipulation of the crude oil feed pressure.

4.3.2 EFFECTS THREE PHASE SEPARATOR PARAMETERS

a. High Pressure Separator operating pressure

Manipulated Variables: Pressure drop and Operating Pressure (Psia)

Unit Op. : HP Separator

Fluid Package: Peng Robinson

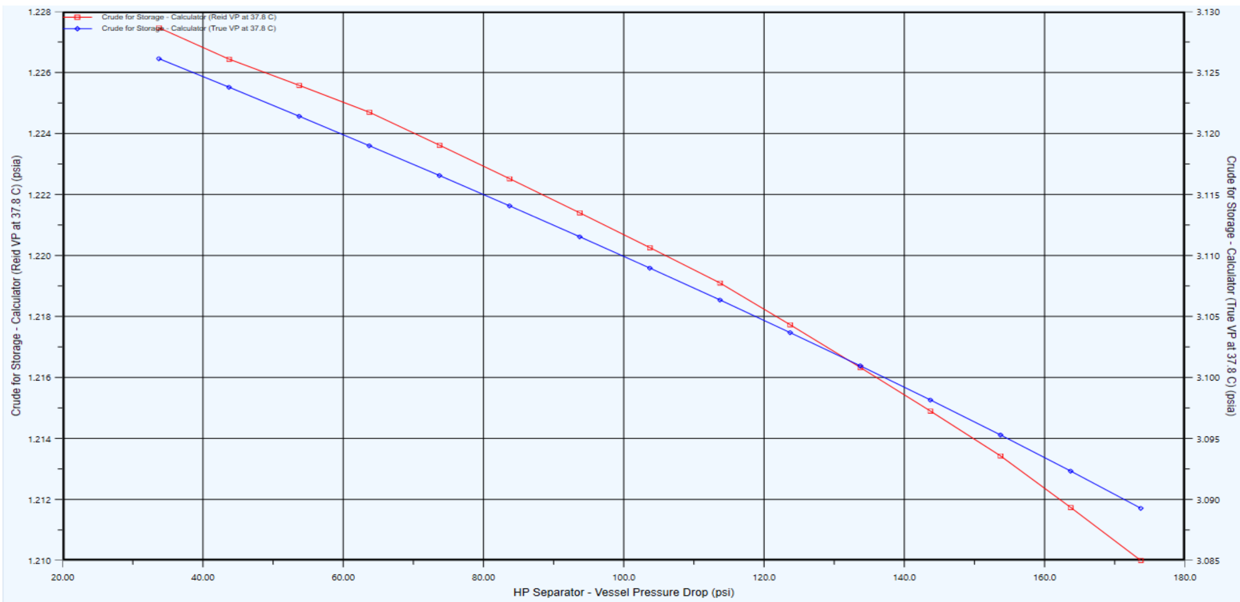

Figure 23.Cendor 2 (H15) HP Separator - Pressure Drop (Psia) using Peng Robinson

Fluid Package: Chao – Seader

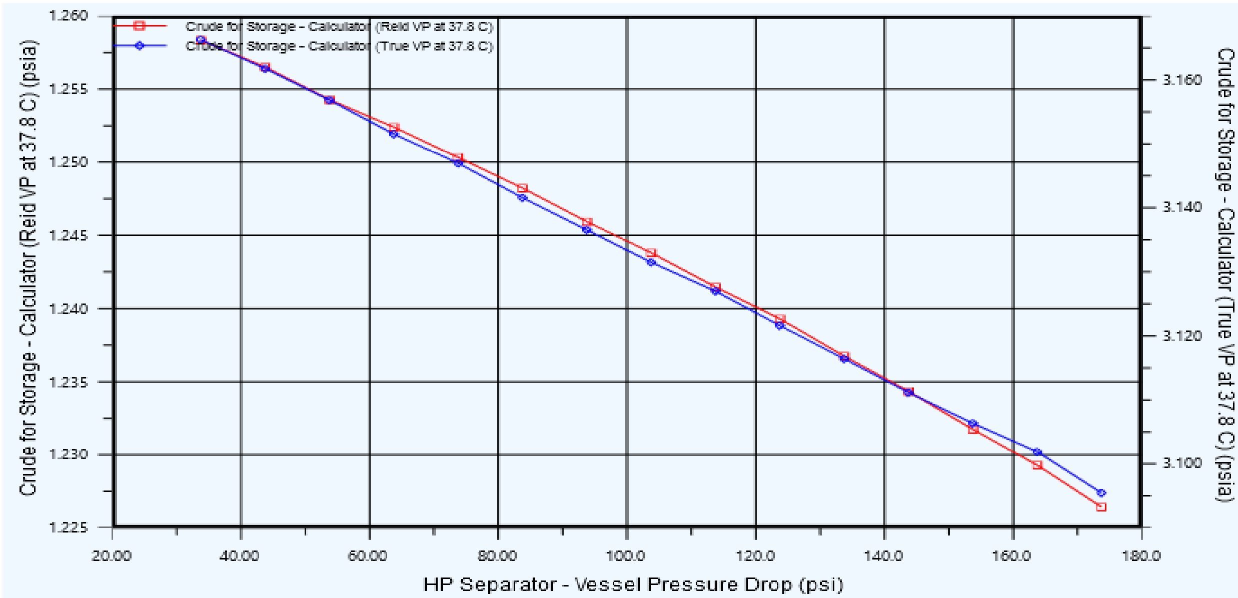

Figure 24. Cendor 2 (H15) HP Separator - Pressure Drop (Psia) using Chao - Seader

Based on the Cendor Phase 2 Development Project Design Basis Memorandum, the high pressure separator is operating at 253.8 psia (17.5 bar), which means the feed need to undergo 79.92 psia pressure drop. For the purpose of these simulations, to determine the operating pressure for the separator, the pressure drop needs to be determined. In the case of this high pressure separator, operating pressure is set at 300 psia and then reduced to 160 psia.

The graph in Figure above shows that as the operating pressure of high pressure separator increases, the stabilized crude product TVP and RVP also increase. The increase in TVP and RVP of the products is due to the fact that, the increase of high pressure separator operating pressure means lowers differential pressure between the incoming crude inlet and the pressure vessel (lower pressure loss). This results in fewer amounts of light components being flashed off as gas phase at the high pressure separator.

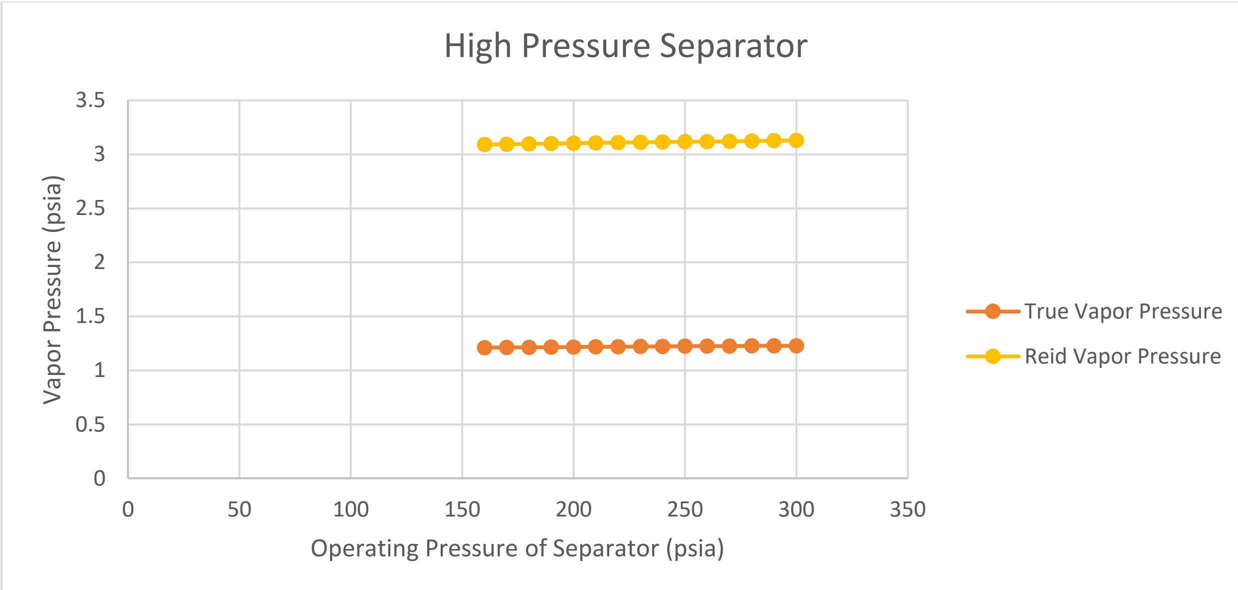

Figure 25. Graph of vapor pressure against operating pressure of the HP separator.

However, as we can see from above graph, the impact is not very significant as the increment in products TVP and RVP happen slowly and not very drastically, which is only the matter of 0.01 psia.

b. Low Pressure Separator operating pressure

Manipulated Variables: Pressure Drop and Operating Pressure (Psia)

Unit Op. : LP Separator

Fluid Package: Peng Robinson

Low Pressure Separator is one of the three phase separators in the crude oil stabilization system which normally operates at 87.04 psia. The light components flashed off from the low pressure separator are sent to the gas stabilization for purification process.

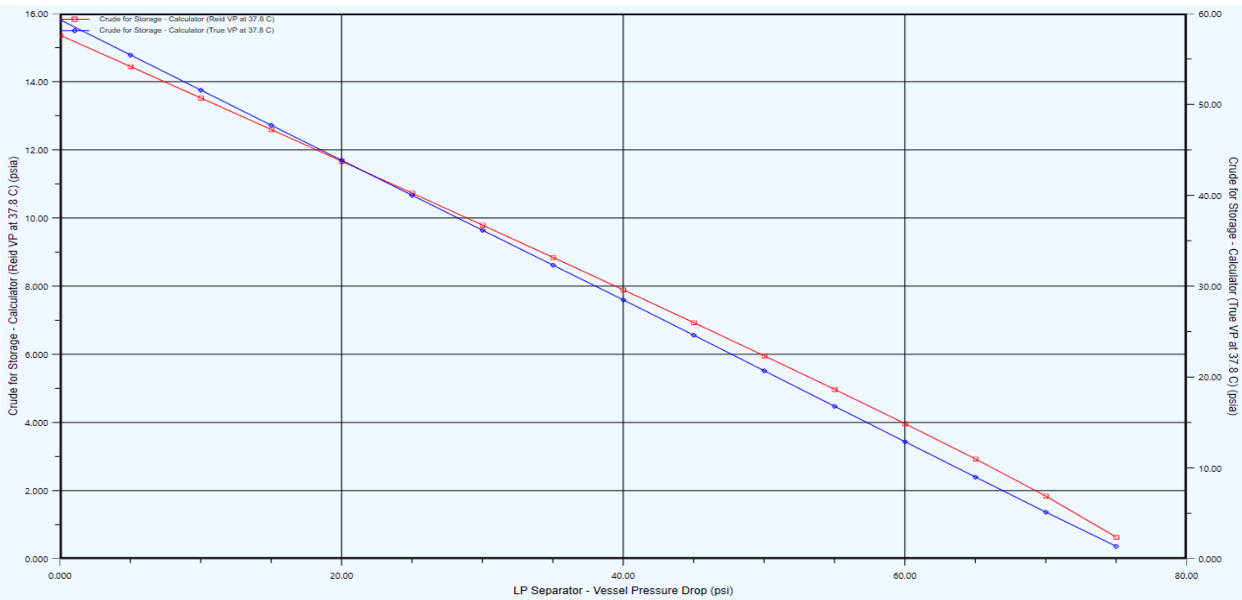

Figure 26. Cendor 2 (H15) LP Separator - Pressure Drop (Psia) using Peng Robinson

Fluid Package: Chao – Seader

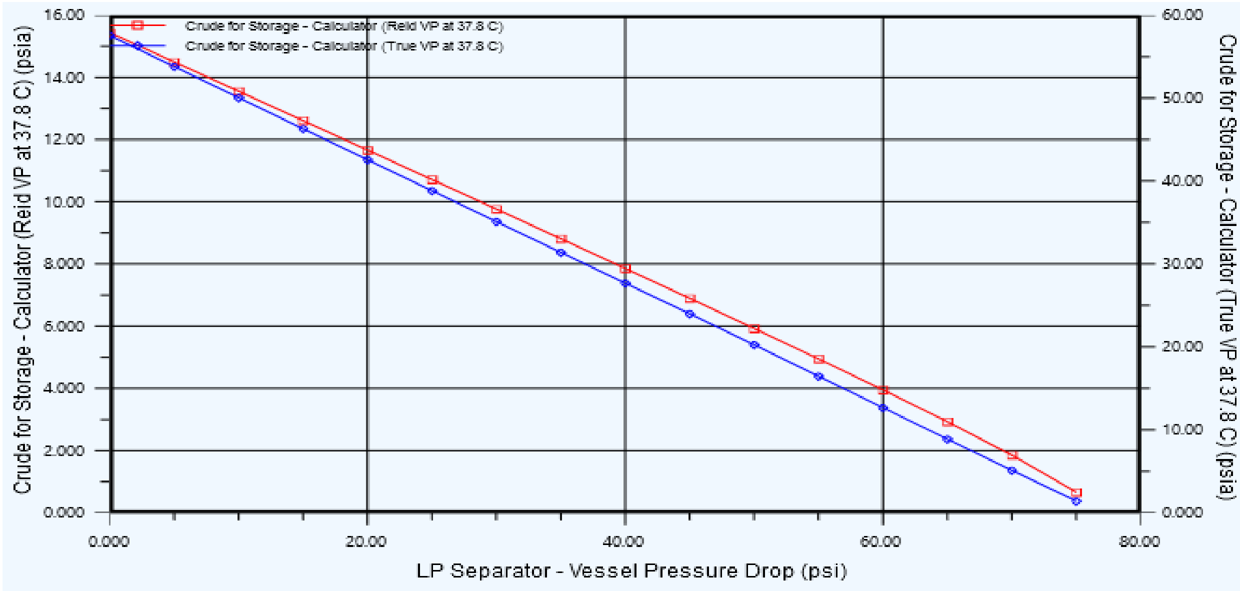

Figure 27. Cendor 2 (H15) LP Separator - Pressure Drop (Psia) using Chao - Seader

Based on the Cendor Phase 2 Development Project Design Basis Memorandum, the low pressure separator is operating at 87.04 psia (6 bar), which means the feed need to undergo 79.66 pressure drop. For the purpose of these simulations, to determine the operating pressure for the separator, the pressure drop needs to be determined. In the case of this high pressure separator, operating pressure is set at 159.7 psia and then reduced to 84.7 psia with interval of 5 psia. The total number of states for this study is 16.

The graph in Figure above, like in high pressure separator, it shows that as the operating pressure of low pressure separator is increased, the stabilized crude product TVP and RVP also increase. The increase in TVP and RVP of the products is due to the fact that the increase in low pressure separator operating pressure, means lowers differential pressure between the incoming crude inlet and the pressure vessel (pressure loss). This results in fewer amounts of light components being flashed off as gas phase at the high pressure separator. Thus, there are still traces amount of volatile component in the rundown crude to storage which contributed to increase of product TVP and RVP.

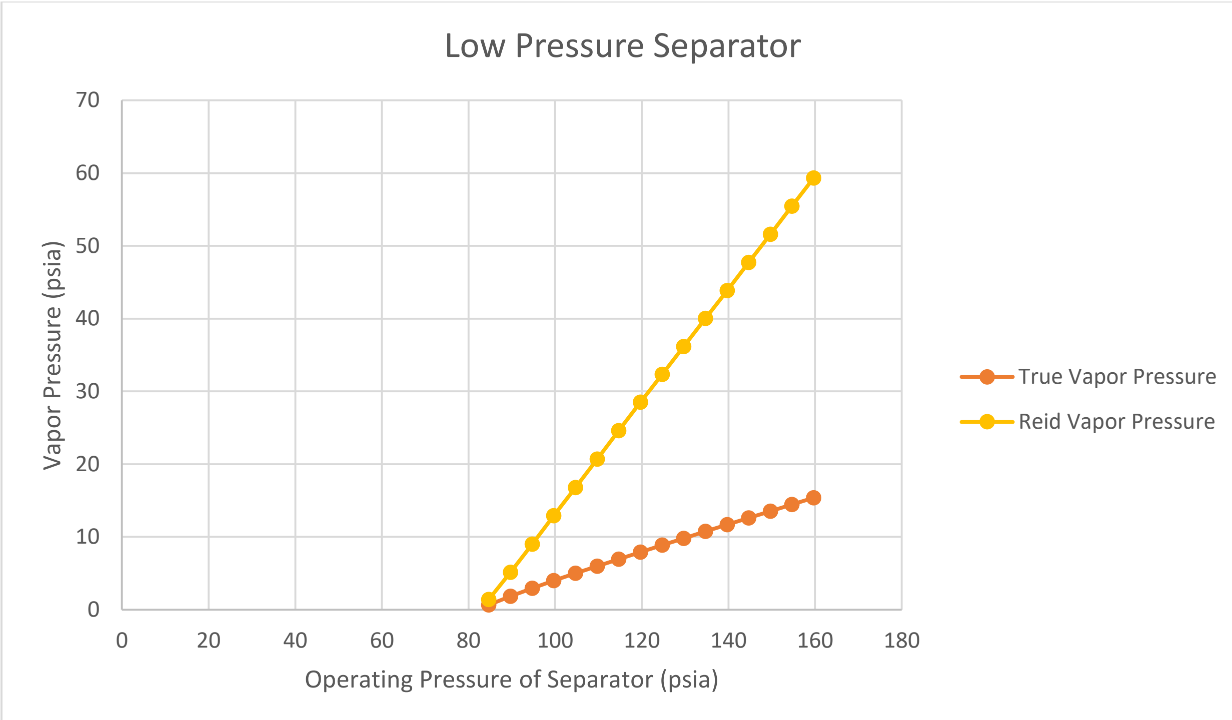

Figure 28. Graph of vapor pressure against operating pressure of the LP separator.

As we can see from the above graph, for the True Vapor Pressure (TVP) to fulfill the requirement of the client, which is TVP less than 10 psia, the operating pressure of the separator should not exceed roughly about 130 psia, or else the TVP would be more than the required vapor pressure. As we can see, this change in the RVP and TVP is more drastic than in the previous case.

c. Degasser operating pressure

Manipulated Variables: Pressure Drop and Operating Pressure (Psia)

Unit Op. : Degasser

Degasser, is the last three phase separator in the crude oil stabilization system which normally operates at 4.369 psia (0.3 bar) at 70 °C. It is normally operating at 300 kPa at 75 – 85 °C. Separated crude oil and off-gas from this Degasser are sent to heat exchanger, and to the tank for storage afterward.

Fluid Package: Peng Robinson

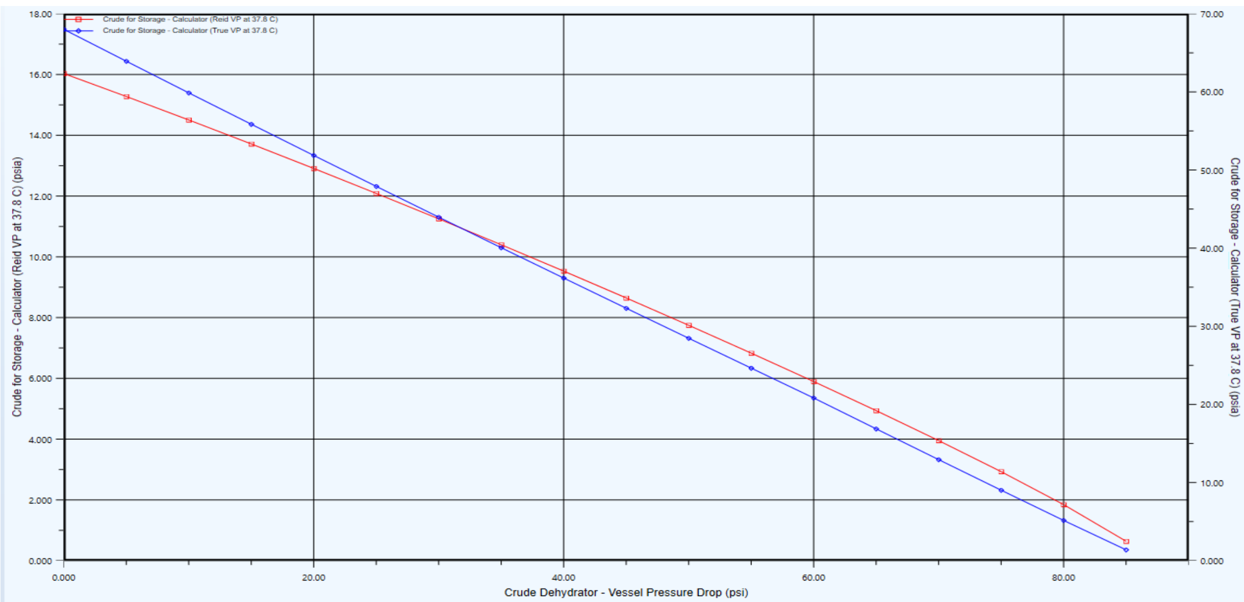

Figure 29. Cendor 2 (H15) Degasser - Pressure Drop (Psia) using Peng Robinson

Fluid Package: Chao – Seader

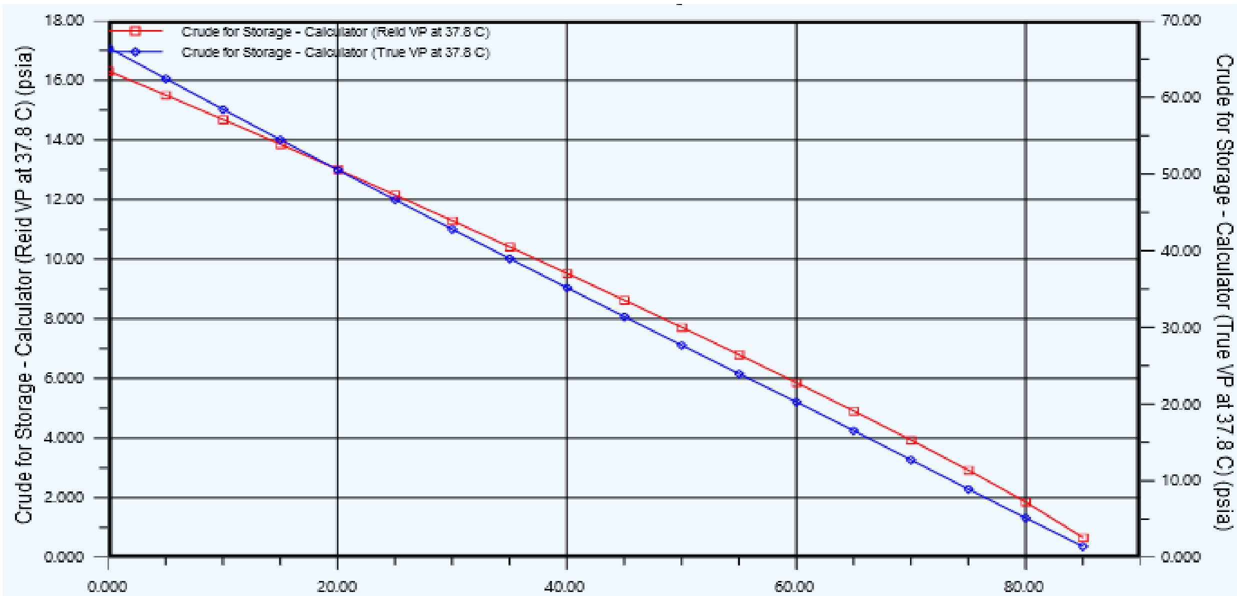

Figure 30. Cendor 2 (H15) Degasser - Pressure Drop (Psia) using Chao - Seader

Based on the Cendor Phase 2 Development Project Design Basis Memorandum, the Degasser is operating at 4.369 psia (0.3 bar), which means the feed need to undergo 82.67 psia pressure drop. For the purpose of these simulations, to determine the operating pressure for the separator, the pressure drop needs to be determined. In the case of this high pressure separator, operating pressure is set at 87.04 psia and then reduced to 2.04 psia with interval of 5 psia. The total number of states for this study is 18.

The graph in Figure above, like previous two cases, it shows that as the operating pressure of low pressure separator is increased, the stabilized crude product TVP and RVP also increase. The increase in TVP and RVP of the products is due to the fact that the increase in low pressure separator operating pressure, means lowers differential pressure between the incoming crude inlet and the pressure vessel (pressure loss). This results in fewer amounts of light components being flashed off as gas phase at the high pressure separator. Thus, there are still traces amount of volatile component in the crud e to storage which contributed to increase of product final TVP and RVP.

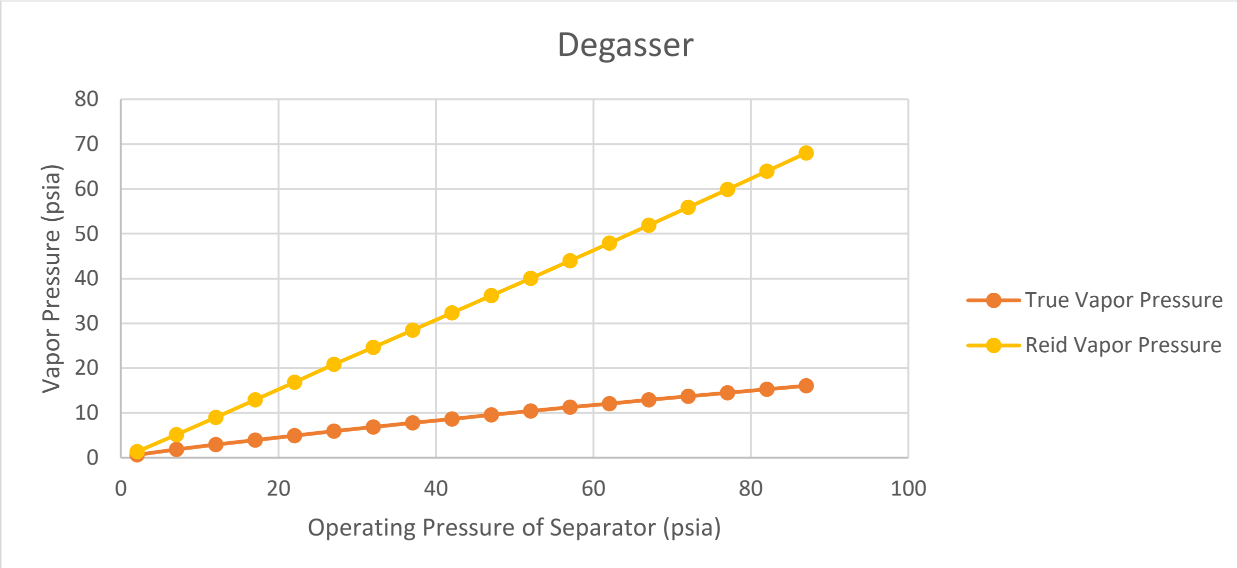

Figure 31. Graph of vapor pressure against operating pressure of the Degasser.

As we can see from the above graph, like the case of low pressure separator, for the True Vapor Pressure (TVP) to fulfill the requirement of the client, which is TVP less than 10 psia, the operating pressure of the separator should not exceed roughly about 50 psia, or else the TVP would be more than the required vapor pressure.

Therefore we can conclude that all the explanations are the same for all three cases of separator.

4.4 EFFECTS OF DIFFERENT OPERATING PRESSURE OF SEPARATOR AND NUMBER OF SEPARATION PROCESS TOWARDS THE FINAL COMPOSITION OF THE CRUDE OIL.

In real plant, the operating pressure of separator and its sequence are very important in determining the quality and the stability of the crude oil. In the process reducing the vapor pressure by flashing off light components, it is very important to ensure that there is not so much loss of the heavier desired product. In this part, compositional analysis is done to investigate whether the process is carried out at its optimum capacity or not, so that there will be less loss of the heavier desired product in the final composition of the stabilized crude oil.

1. Operating Pressure of Separator

a. High Pressure Separator

b. Low Pressure Separator

c. Degasser

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High Pressure Separators

High Pressure separators are primary separation devices used for segregation of the three phases i.e. Oil, Water and Gas from the initial inlet stream coming outside the Oil Wells and moving to medium and low pressure separators before ending up in the storage tank.

High pressure is essential for the lighter components in the liquid phase to stabilize therefore resulting in quicker retention time and separation of liquids from each other. However, the high pressure must also be retained at the optimum level so that it does not cause the lighter component in the liquid phase end up in the outlet gas stream.

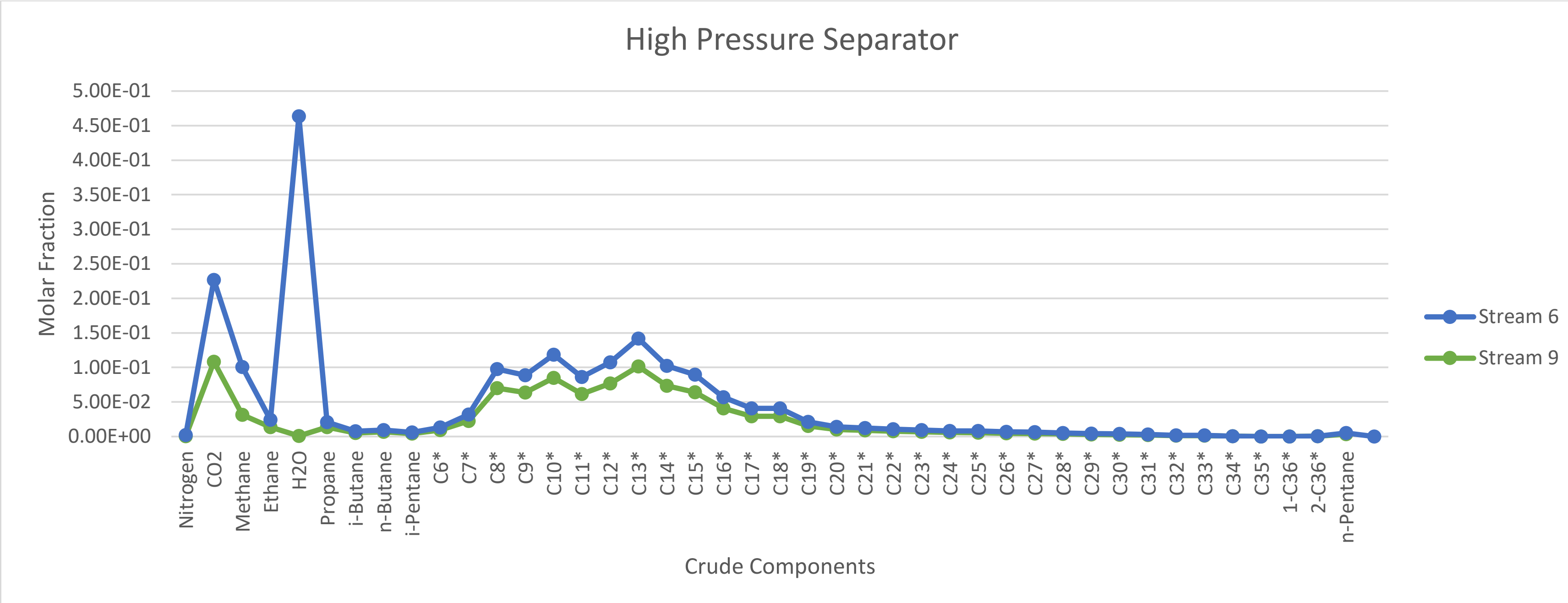

Figure 32. Composition of inlet and outlet of HP Separator.

As we can see from the graph, stream that enters the separator (stream 6) has higher fraction of light components such as Nitrogen, Carbon Dioxide than the stream that exits the separator (stream 9). This is because the light components have been flashed off in the separator due to the pressure drop undergone by the stream in the separator. Fraction of desired product such as (C6 - C18) have also been flashed off in the separators.

Low Pressure Separator

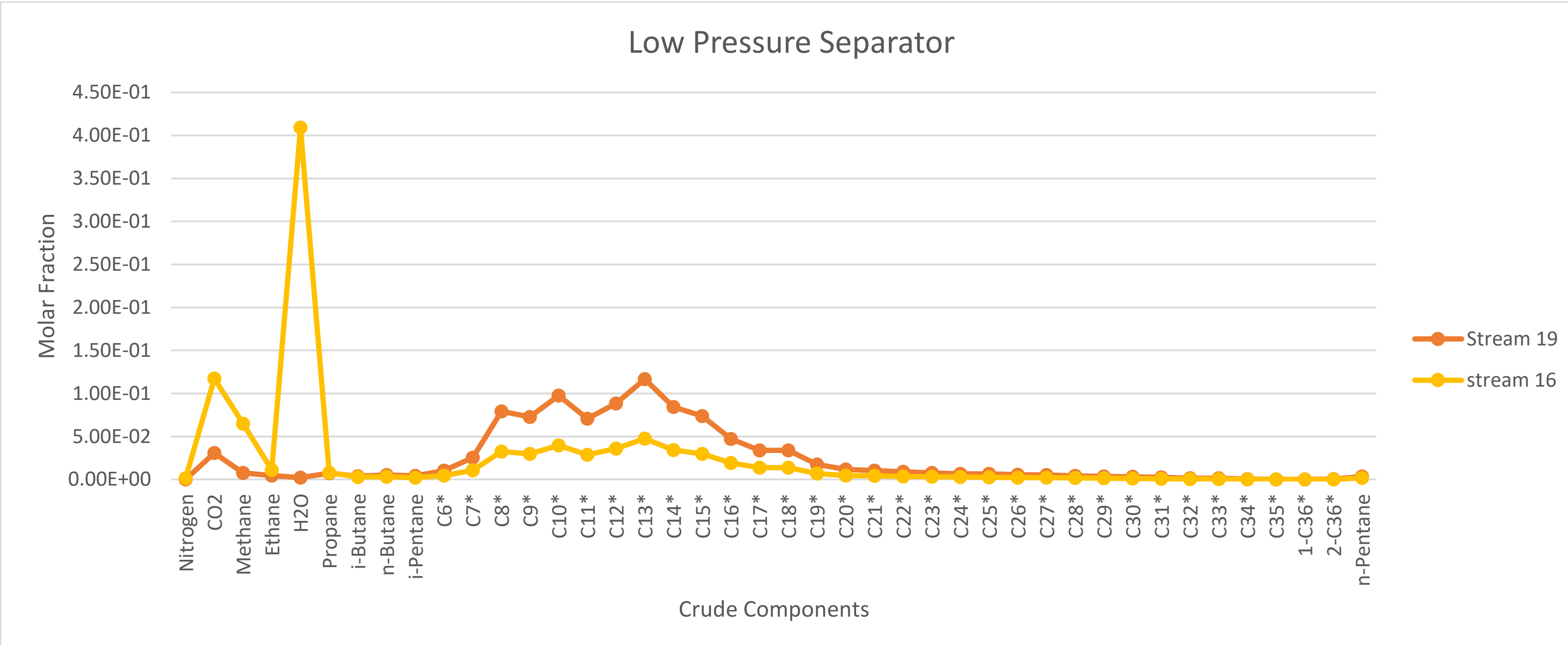

Figure 33. Composition of inlet and outlet of LP Separator.

As we can see from the graph, stream that enters the separator has higher fraction of light components such as Nitrogen, Carbon Dioxide than the stream at the outlet of the separator. In fact in this case of low pressure separator, there are more fraction of light components being flashed off , compared with the case of high pressure separator. This is due to lower operating pressure of the separator. The lower the operating pressure of the separator means bigger pressure loss. Hence, as a result of more amount of lighter components being flashed off, it means there are higher fraction of desired intermediate product such as (C6-C20) present in the outlet stream.

Degasser

The task of the Degasser is the removal of Carbon Dioxide gas and insoluble, emulsified water from oil. Electrostatic field is generated between the electrodes by means of power units, at a voltage function mainly of the types of oil to be treated. The emulsion is introduced under the electrodes by means of distributors.

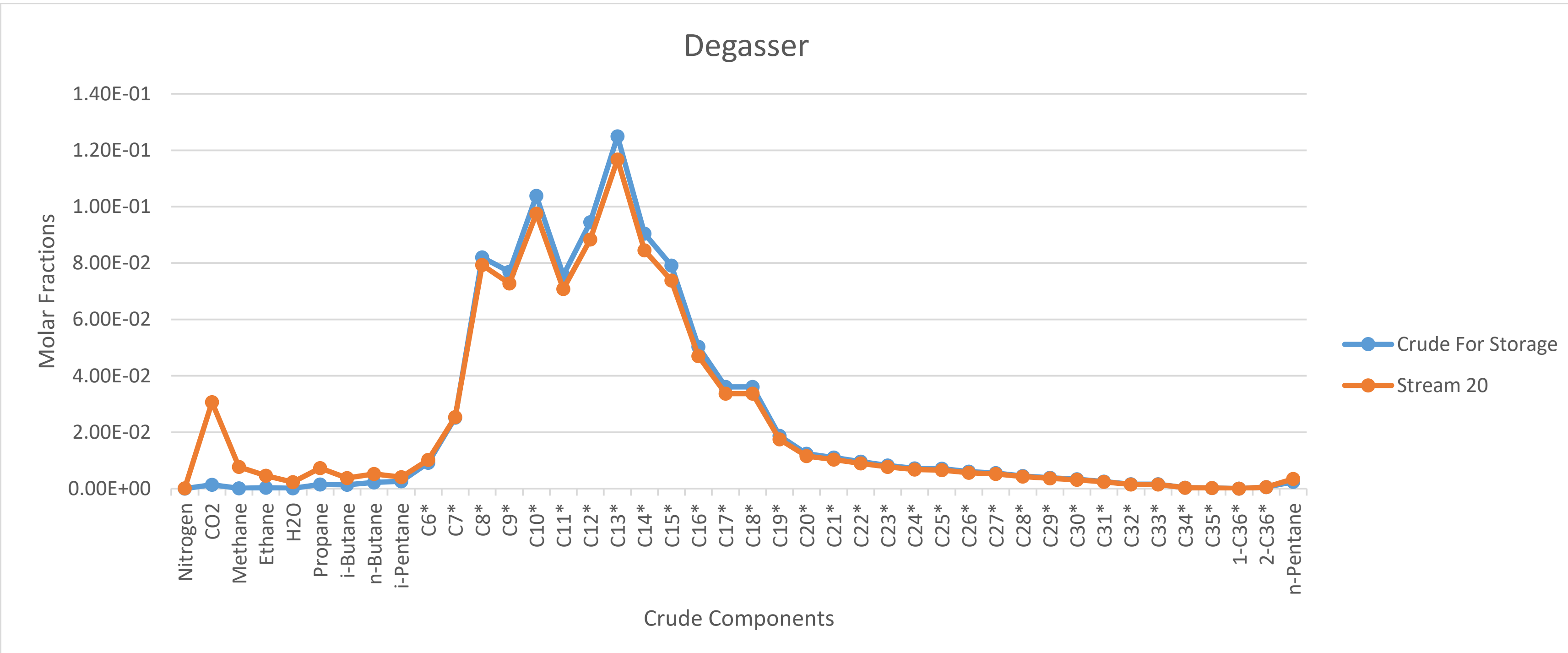

Figure 34.Composition of inlet and outlet of Degasser.

At this Degasser, its operating pressure is 4.369 psia (0.3 bar). As a result of bigger pressure loss, there are more light components such as Carbon Dioxide and some emulsified water from being flashed off. Hence, there are more fraction of desired product at the outlet stream of the crude oil.

This study aims to simulate an industrial case study which is based on Cendor Phase 2 Field Project operations in order to obtain a stabilized crude with maximum Reid Vapor Pressure (RVP) of 8 psia. The purpose of producing a stabilized crude oil with the lowest vapor pressure as possible is to make sure that there is not wastage during the transport of the crude oil, hence optimize the profit of the company. Based on the simulation done, and the results obtained, the parameters that has been manipulated in the previous part definitely can affect the efficiency of the separation of the crude oil. In this case, with the correct setup of some parameters such as the pressure drop at the separators, it can result in a production of a very high quality crude oil with the correct amount.

From this study, it is found out that with the correct flow of process and arrangement of unit operations, it is fairly easy to produce the crude oil that fulfills the requirement set by the client which is below 8 psia regardless of the extreme condition of the parameters. As we can see from the simulation, all the the final value of Reid Vapor Pressure (RVP) and True Vapor Pressure (TVP) of the crude oil is between 1 psia to 6 psia which is very much under the requirement set by the client.

In the simulation using Peng Robinson as the fluid package, when the pressure drop of the High Pressure Separator is minimum which is 33.7 psia, the Reid Vapor Pressure (RVP) and True Vapor Pressure (TVP) are 1.227 and 3.126 respectively. Those readings decrease to 1.210 and 3.089 respectively when the pressure drop increases to its maximum which is 173.7 psia.

In the simulation using Peng Robinson as the fluid package, when the temperature of the feed from the High Pressure Well is set at the highest which is 100 °C, the final reading of the Read Vapor Pressure (RVP) and True Vapor Pressure (TVP) is 1.224 psia and 3.141 psia respectively. When the temperature is set to the lowest which is 10 °C, the Reid Vapor Pressure (RVP) and the True Vapor Pressure (TVP) is 1.235 psia and 3.151 respectively. From the reading, we can see that the difference in the crude oil final vapor pressure is not that much in the case of the temperature set as the manipulated variables.

As we look at the influence of the pressure of the feed, the final vapor pressure of stabilized crude oil generally decreases with the increase of pressure. We can see from the simulation using Peng Robinson as the fluid package, as the pressure of the High Pressure well is at its minimum which is 800 psia, the final reading of Reid Vapor Pressure (RVP) and True Vapor Pressure (TVP) of the stabilized crude oil would be 1.232 psia and 3.144 psia respectively. As the pressure of the High Pressure well is increased to its maximum which is 9800 psia, the final reading of Reid Vapor Pressure (RVP) and True Vapor Pressure (TVP) of the stabilized crude oil would be 1.227 psia and 3.142 respectively. Therefore, like temperature, as we make the pressure as a manipulated parameter, the final readings of vapor pressure of the stabilized crude oil still change, but they don't change that much.

On top of that, as we talk about the fluid property package used, it can be concluded that both property package gives readings that are quite similar. Therefore, apart from conventional Peng Robinson used for organic compound, Chao – Seader can also act as alternative method in order to produce final calculation that are as accurate as possible. Lastly in the compositional analysis, the final composition of crude oil is studied and it was found out that the composition is theoretically consistent with its final vapor pressure. For instance, it was found out that the stabilized crude oil that has a lower Vapor Pressure reading has a higher percentage of heavy components compared to the ones which has a lower vapor pressure reading.

In a nutshell, all the reading obtained from this simulation study has been positive and consistent with the theoretical knowledge and the main objectives of this study have been achieved.

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APPENDIX I

DRAWINGS, SCHEMATIC AND PFDS OF CENDOR PHASE 2 FIELD PROJECT

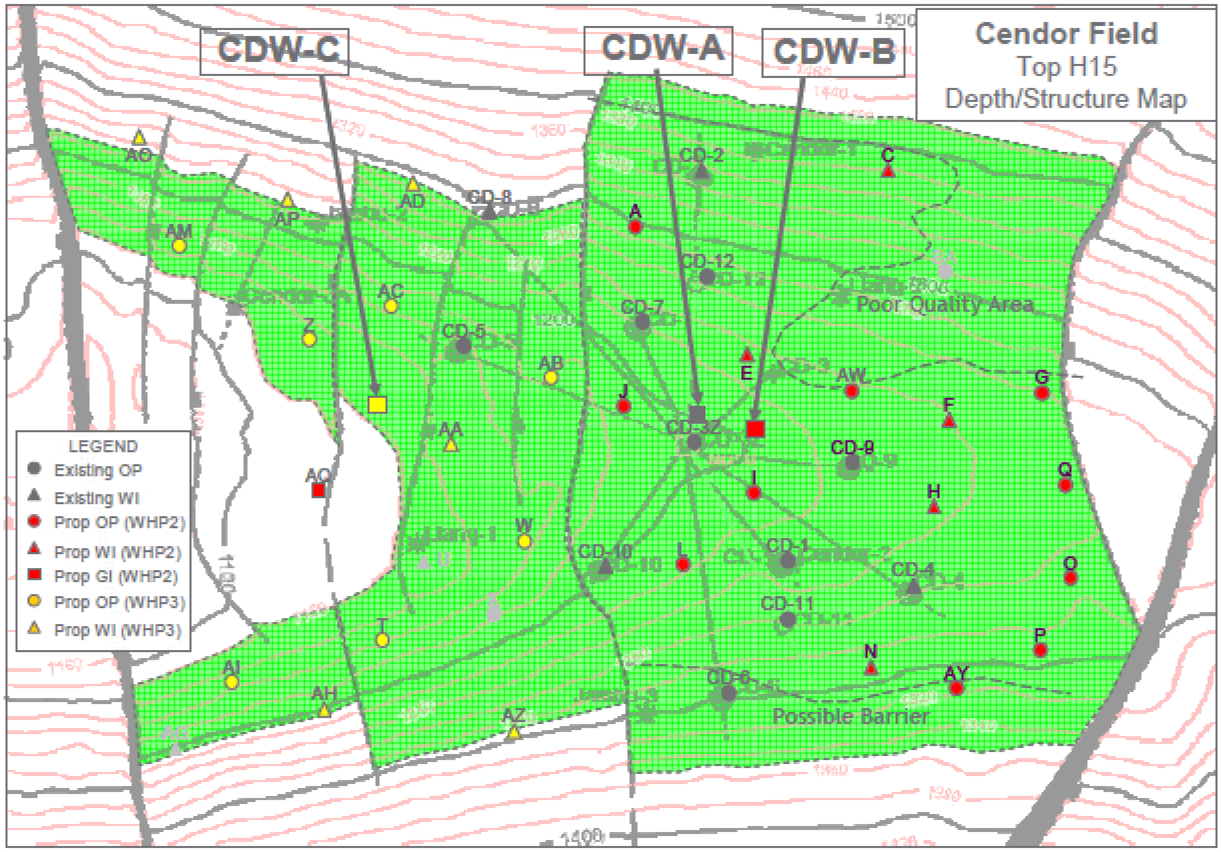

Figure 35. Proposed Cendor Development Wellhead Platforms

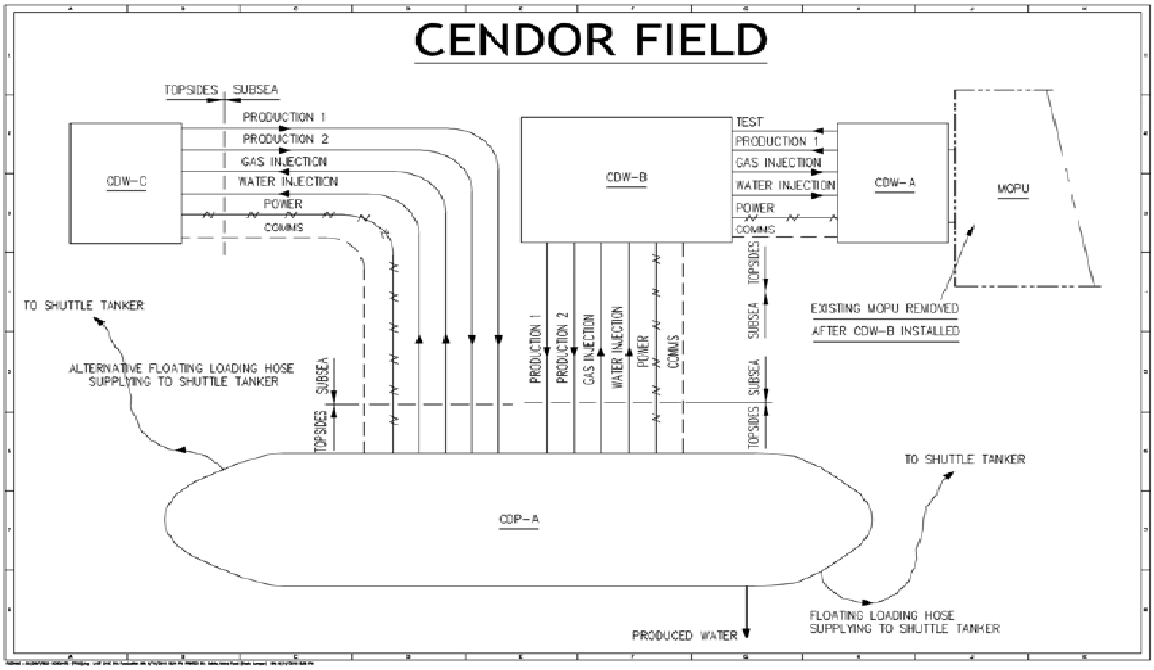

Figure 36. Overall Schematic Of Cendor Field.

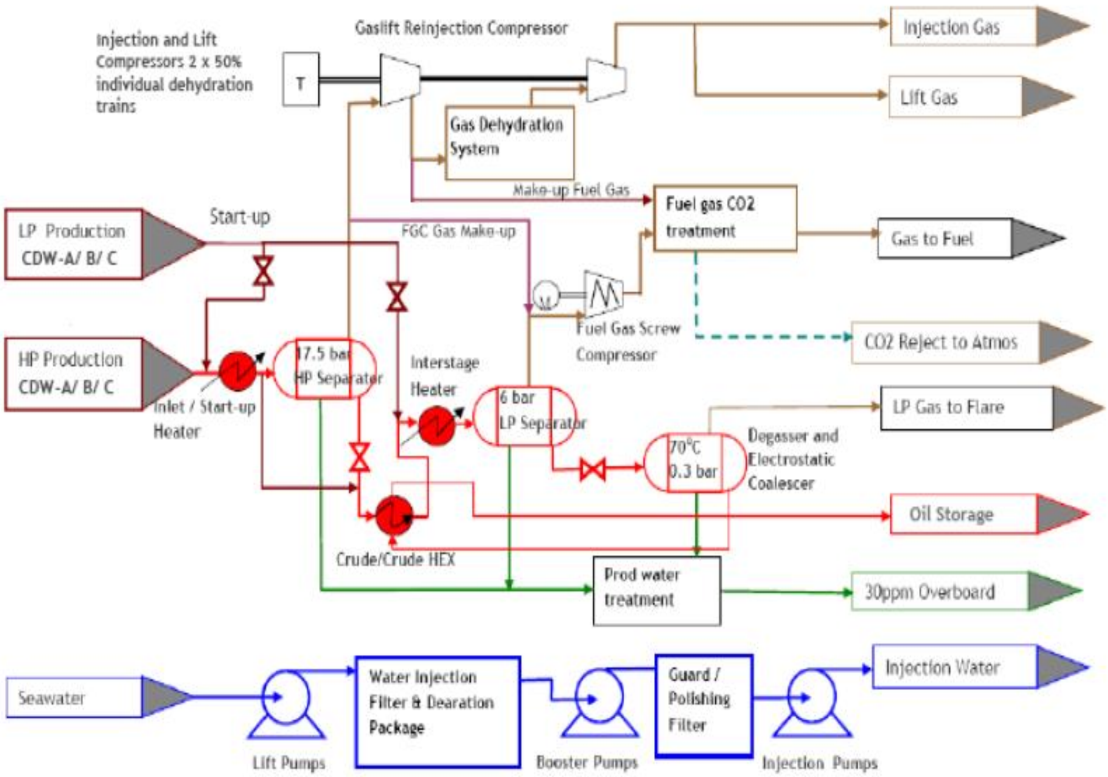

Figure 37. General Processs Schematic Diagram of Cendor Phase 2 Crude Stabilization Process

APPENDIX II

BASIS OF SIMULATIONS, CRUDE OIL COMPOSITION

	CD-5	Jambu 3 DST6	Jambu 3 DST5	Cendor 2 (H15)
N2	0.191	0.440	0.630	0.330
CO_2	32.745	7.560	10.510	22.040
H_2S	-	-	-	-
C1	12.130	13.100	11.990	12.880
C2	2.083	1.830	1.910	1.980
C3	1.351	1.060	1.120	1.330
iC4	0.519	0.360	0.370	0.440
nC4	0.617	0.330	0.370	0.540
iC5	0.451	0.180	0.210	0.330
nC5	0.372	0.130	0.150	0.270
C6*	1.363	0.300	0.110	0.710
C7+*	-	74.710	72.630	-
C6H6	0.248	-	-	-
C7*	2.281	-	-	1.680
C8H10	0.912	-	-	-
C8*	4.233	-	-	5.160
C9*	2.156	-	-	4.690
C10*	3.949	-	-	6.260
C11*	4.347	-	-	4.540
C12*	3.962	-	-	5.660
C13*	4.649	-	-	7.480
C14*	4.379	-	-	5.410
C15*	3.545	-	-	4.730
C16*	2.165	-	-	3.010
C17*	1.716	-	-	2.160
C18*	1.694	-	-	2.160
C19*	0.949	-	-	1.120
C20*	1.580	-	-	0.740
C21*	0.604	-	-	0.660
C22*	0.455	-	-	0.570
C23*	0.494	-	-	0.490
C24*	0.503	-	-	0.430
C25*	0.402	-	-	0.420
C26*	0.438	-	-	0.360
C27*	0.346	-	-	0.330
C28*	0.334	-	-	0.270
C29*	0.299	-	-	0.230
C30*	0.244	-	-	0.200
C31*	0.172	-	-	0.150
C32*	0.167	-	-	0.090
C33*	0.101	-	-	0.090
C34*	0.098	-	-	0.020
C35*	0.076	-	-	0.010
C36+*	0.681	-	-	0.030

Figure 38. Basis of Simulation according to Design Basis Memorandum. Crude oil composition coming from H15 well can be seen at far right of the table.

Components	Mole Fraction	Vapor Phase	Liquid Phase
Nitrogen	3.30E-03	9.50E-03	1.73E-04
CO2	0.2204	0.552450599	5.28E-02
Methane	0.1288	0.35384145	1.52E-02
Ethane	1.98E-02	4.47E-02	7.22E-03
H2O	-	-	-
Propane	1.33E-02	2.12E-02	9.32E-03
i-Butane	4.40E-03	4.61E-03	4.29E-03
n-Butane	5.40E-03	4.75E-03	5.73E-03
i-Pentane	3.30E-03	1.62E-03	4.15E-03
C6*	7.10E-03	1.30E-03	1.00E-02
C7*	1.68E-02	1.35E-03	2.46E-02
C8*	5.16E-02	2.02E-03	7.66E-02
C9*	4.69E-02	7.48E-04	7.02E-02
C10*	6.26E-02	4.19E-04	9.40E-02
C11*	4.54E-02	1.50E-04	6.82E-02
C12*	5.66E-02	1.01E-04	8.51E-02
C13*	7.48E-02	7.44E-05	0.112512
C14*	5.41E-02	2.95E-05	8.14E-02
C15*	4.73E-02	1.16E-05	7.12E-02
C16*	3.01E-02	3.41E-06	4.53E-02
C17*	2.16E-02	1.13E-06	3.25E-02
C18*	2.16E-02	5.89E-07	3.25E-02
C19*	1.12E-02	1.76E-07	1.69E-02
C20*	7.40E-03	6.83E-08	1.11E-02
C21*	6.60E-03	3.06E-08	9.93E-03
C22*	5.70E-03	1.45E-08	8.58E-03
C23*	4.90E-03	7.16E-09	7.37E-03
C24*	4.30E-03	3.71E-09	6.47E-03
C25*	4.20E-03	2.07E-09	6.32E-03
C26*	3.60E-03	1.00E-09	5.42E-03
C27*	3.30E-03	5.03E-10	4.97E-03
C28*	2.70E-03	2.33E-10	4.06E-03
C29*	2.30E-03	1.12E-10	3.46E-03
C30*	2.00E-03	5.37E-11	3.01E-03
C31*	1.50E-03	2.09E-11	2.26E-03
C32*	9.00E-04	6.54E-12	1.35E-03
C33*	9.00E-04	3.29E-12	1.35E-03
C34*	2.00E-04	3.56E-13	3.01E-04
C35*	1.00E-04	8.14E-14	1.50E-04
1-C36*	-	-	-
2-C36*	3.00E-04	6.94E-15	4.51E-04
n-Pentane	2.70E-03	1.11E-03	3.50E-03

Figure 39. Inlet Composition of crude oil (at the feed)

Components	Mole Fraction	Liquid Phase
Nitrogen	6.04E-07	6.04E-07
CO2	1.35E-03	1.35E-03
Methane	1.45E-04	1.45E-04
Ethane	3.42E-04	3.42E-04
H2O	1.08E-04	1.08E-04
Propane	1.42E-03	1.42E-03
i-Butane	1.36E-03	1.36E-03
n-Butane	2.23E-03	2.23E-03
i-Pentane	2.60E-03	2.60E-03
C6*	9.14E-03	9.14E-03
C7*	2.52E-02	2.52E-02
C8*	8.21E-02	8.21E-02
C9*	7.69E-02	7.69E-02
C10*	0.103881	0.103815
C11*	7.56E-02	7.56E-02
C12*	9.44E-02	9.44E-02
C13*	0.124919	0.124912
C14*	9.04E-02	9.04E-02
C15*	7.90E-02	7.90E-02
C16*	5.03E-02	5.03E-02
C17*	3.61E-02	3.61E-02
C18*	3.61E-02	3.61E-02
C19*	1.87E-02	1.87E-02
C20*	1.24E-02	1.24E-02
C21*	1.10E-02	1.10E-02
C22*	9.53E-03	9.53E-03
C23*	8.19E-03	8.19E-03
C24*	7.19E-03	7.19E-03
C25*	7.02E-03	7.02E-03
C26*	6.02E-03	6.02E-03
C27*	5.52E-03	5.52E-03
C28*	4.51E-03	4.51E-03
C29*	3.84E-03	3.84E-03
C30*	3.34E-03	3.34E-03
C31*	2.51E-03	2.51E-03
C32*	1.50E-03	1.50E-03
C33*	1.50E-03	1.50E-03
C34*	3.34E-04	3.34E-04
C35*	1.67E-04	1.67E-04
1-C36*	-	-
2-C36*	5.01E-04	5.01E-04
n-Pentane	2.43E-03	2.43E-03

Figure 40. Final composition of crude oil for storage and transport.

APPENDIX III

PRELIMINARY ANALYSIS DATA TABLES

DATA TABLES OF SIMULATIONS USING PENG ROBINSON AS FLUID PACKAGE.

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well HP - Std Ideal Liq Vol Fl...	0.0000	1000	2000	3000	4000	5000	6000
Crude for Storage - Calculator (Reid VP at 37....	1.142	1.150	1.158	1.166	1.173	1.179	1.185
Crude for Storage - Calculator (True VP at 37....	2.984	2.999	3.013	3.026	3.037	3.048	3.059
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well HP - Std Ideal Liq Vol Fl...	7000	8000	9000	10000.	1.100e+004	1.200e+004	1.300e+004
Crude for Storage - Calculator (Reid VP at 37....	1.191	1.196	1.201	1.205	1.209	1.213	1.217
Crude for Storage - Calculator (True VP at 37....	3.068	3.077	3.086	3.094	3.102	3.109	3.116
State	State 15	State 16	State 17	State 18	State 19	State 20	State 21
Cendor 2 (H15) Well HP - Std Ideal Liq Vol Fl...	1.400e+004	1.500e+004	1.600e+004	1.700e+004	1.800e+004	1.900e+004	2.000e+004
Crude for Storage - Calculator (Reid VP at 37....	1.221	1.224	1.227	1.230	1.233	1.236	1.239
Crude for Storage - Calculator (True VP at 37....	3.123	3.129	3.135	3.141	3.146	3.152	3.157

Table 9. Cendor 2 Well HP - Std Ideal Liq Vol Flow (barrel/day) (Fig.7, Pg.40)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well LP - Std Ideal Liq Vol Flo...	0.0000	1000	2000	3000	4000	5000	6000
Crude for Storage - Calculator (Reid VP at 37....	1.309	1.301	1.293	1.287	1.281	1.275	1.270
Crude for Storage - Calculator (True VP at 37....	3.261	3.250	3.239	3.229	3.220	3.212	3.204
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well LP - Std Ideal Liq Vol Flo...	7000	8000	9000	10000.	1.100e+004	1.200e+004	1.300e+004
Crude for Storage - Calculator (Reid VP at 37....	1.265	1.261	1.257	1.253	1.250	1.247	1.243
Crude for Storage - Calculator (True VP at 37....	3.197	3.190	3.184	3.178	3.173	3.167	3.162
State	State 15	State 16	State 17	State 18	State 19	State 20	State 21
Cendor 2 (H15) Well LP - Std Ideal Liq Vol Flo...	1.400e+004	1.500e+004	1.600e+004	1.700e+004	1.800e+004	1.900e+004	2.000e+004
Crude for Storage - Calculator (Reid VP at 37....	1.241	1.238	1.235	1.233	1.231	1.229	1.226
Crude for Storage - Calculator (True VP at 37....	3.158	3.153	3.149	3.145	3.142	3.138	3.135

Table 10. Cendor 2 Well LP - Std Ideal Liq Vol Flow (barrel/day) (Fig.9, Pg.42)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well Freewater HP - Std Ideal...	500.0	1000	1500	2000	2500	3000	3500
Crude for Storage - Calculator (Reid VP at 37....	1.231	1.231	1.232	1.232	1.233	1.233	1.233
Crude for Storage - Calculator (True VP at 37....	3.140	3.142	3.143	3.144	3.145	3.147	3.148
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well Freewater HP - Std Ideal...	4000	4500	5000	5500	6000	6500	7000
Crude for Storage - Calculator (Reid VP at 37....	1.234	1.234	1.235	1.235	1.236	1.236	1.236
Crude for Storage - Calculator (True VP at 37....	3.149	3.150	3.152	3.153	3.154	3.155	3.156
State	State 15	State 16	State 17	State 18	State 19	State 20	
Cendor 2 (H15) Well Freewater HP - Std Ideal...	7500	8000	8500	9000	9500	10000.	
Crude for Storage - Calculator (Reid VP at 37....	1.237	1.237	1.238	1.238	1.238	1.239	
Crude for Storage - Calculator (True VP at 37....	3.157	3.158	3.159	3.160	3.161	3.162	

Table 11. Cendor 2 Well Freewater HP - Std Ideal Liq Vol Flow (barrel/day) (Fig.11, Pg.44)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well Freewater LP- - Std Idea...	500.0	1000	1500	2000	2500	3000	3500
Crude for Storage - Calculator (Reid VP at 37....	1.245	1.239	1.234	1.229	1.225	1.221	1.217
Crude for Storage - Calculator (True VP at 37....	3.173	3.161	3.149	3.138	3.128	3.118	3.109
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well Freewater LP- - Std Idea...	4000	4500	5000	5500	6000	6500	7000
Crude for Storage - Calculator (Reid VP at 37....	1.213	1.210	1.206	1.203	1.200	1.197	1.194
Crude for Storage - Calculator (True VP at 37....	3.100	3.092	3.084	3.077	3.070	3.063	3.057
State	State 15	State 16	State 17	State 18	State 19	State 20	
Cendor 2 (H15) Well Freewater LP- - Std Idea...	7500	8000	8500	9000	9500	10000.	
Crude for Storage - Calculator (Reid VP at 37....	1.192	1.189	1.187	1.185	1.183	1.180	
Crude for Storage - Calculator (True VP at 37....	3.051	3.045	3.039	3.034	3.029	3.024	

Table 12. Cendor 2 Well Freeewater LP - Std Ideal Liq Vol Flow (barrel/day) (Fig.13, Pg.46)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well HP - Temperature [C]	10.00	15.00	20.00	25.00	30.00	35.00	40.00
Crude for Storage - Calculator (Reid VP at 37....	1.235	1.235	1.235	1.235	1.235	1.235	1.234
Crude for Storage - Calculator (True VP at 37....	3.151	3.150	3.149	3.148	3.147	3.146	3.146
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well HP - Temperature [C]	45.00	50.00	55.00	60.00	65.00	70.00	75.00
Crude for Storage - Calculator (Reid VP at 37....	1.234	1.233	1.232	1.232	1.231	1.230	1.229
Crude for Storage - Calculator (True VP at 37....	3.145	3.144	3.144	3.143	3.143	3.143	3.142
State	State 15	State 16	State 17	State 18	State 19		
Cendor 2 (H15) Well HP - Temperature [C]	80.00	85.00	90.00	95.00	100.0		
Crude for Storage - Calculator (Reid VP at 37....	1.229	1.228	1.227	1.226	1.224		
Crude for Storage - Calculator (True VP at 37....	3.142	3.142	3.142	3.142	3.141		

Table 13. Cendor 2 (H15) Well HP - Temperature (°C) (Fig.15, Pg.48)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well LP - Temperature [C]	10.00	15.00	20.00	25.00	30.00	35.00	40.00
Crude for Storage - Calculator (Reid VP at 37....	1.801	1.746	1.692	1.640	1.590	1.541	1.493
Crude for Storage - Calculator (True VP at 37....	4.494	4.359	4.229	4.104	3.983	3.866	3.753
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well LP - Temperature [C]	45.00	50.00	55.00	60.00	65.00	70.00	75.00
Crude for Storage - Calculator (Reid VP at 37....	1.447	1.402	1.358	1.315	1.273	1.232	1.192
Crude for Storage - Calculator (True VP at 37....	3.644	3.538	3.435	3.335	3.238	3.143	3.052
State	State 15	State 16	State 17	State 18	State 19		
Cendor 2 (H15) Well LP - Temperature [C]	80.00	85.00	90.00	95.00	100.0		
Crude for Storage - Calculator (Reid VP at 37....	1.153	1.114	1.077	1.041	1.005		
Crude for Storage - Calculator (True VP at 37....	2.962	2.874	2.789	2.706	2.625		

Table 14. Cendor 2 (H15) Well LP - Temperature (°C) (Fig.17, Pg.50)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well HP - Pressure [psia]	300.0	800.0	1300	1800	2300	2800	3300
Crude for Storage - Calculator (Reid VP at 37....	1.228	1.232	1.232	1.232	1.232	1.232	1.231
Crude for Storage - Calculator (True VP at 37....	3.135	3.144	3.144	3.144	3.143	3.143	3.143
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well HP - Pressure [psia]	3800	4300	4800	5300	5800	6300	6800
Crude for Storage - Calculator (Reid VP at 37....	1.231	1.231	1.230	1.230	1.230	1.229	1.229
Crude for Storage - Calculator (True VP at 37....	3.143	3.143	3.143	3.143	3.143	3.142	3.142
State	State 15	State 16	State 17	State 18	State 19	State 20	
Cendor 2 (H15) Well HP - Pressure [psia]	7300	7800	8300	8800	9300	9800	
Crude for Storage - Calculator (Reid VP at 37....	1.229	1.229	1.228	1.228	1.227	1.227	
Crude for Storage - Calculator (True VP at 37....	3.142	3.142	3.142	3.142	3.142	3.142	

Table 15. Cendor 2 (H15) Well HP - Pressure (Psia) (Fig.19, Pg.52)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well LP - Pressure [psia]	156.0	656.0	1156	1656	2156	2656	3156
Crude for Storage - Calculator (Reid VP at 37....	0.2603	1.266	1.278	1.265	1.251	1.237	1.222
Crude for Storage - Calculator (True VP at 37....	0.4319	3.222	3.251	3.219	3.187	3.154	3.122
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well LP - Pressure [psia]	3656	4156	4656	5156	5656	6156	6656
Crude for Storage - Calculator (Reid VP at 37....	1.208	1.194	1.180	1.166	1.151	1.137	1.123
Crude for Storage - Calculator (True VP at 37....	3.089	3.057	3.024	2.991	2.959	2.927	2.895
State	State 15	State 16	State 17	State 18	State 19	State 20	
Cendor 2 (H15) Well LP - Pressure [psia]	7156	7656	8156	8656	9156	9656	
Crude for Storage - Calculator (Reid VP at 37....	1.110	1.096	1.082	1.068	1.055	1.041	
Crude for Storage - Calculator (True VP at 37....	2.863	2.832	2.800	2.769	2.739	2.708	

Table 16. Cendor 2 (H15) Well LP - Pressure (Psia) (Fig.21, Pg.54)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
HP Separator - Vessel Pressure Drop [psi]	33.70	43.70	53.70	63.70	73.70	83.70	93.70
Crude for Storage - Calculator (Reid VP at 37....	1.227	1.226	1.226	1.225	1.224	1.223	1.221
Crude for Storage - Calculator (True VP at 37....	3.126	3.124	3.121	3.119	3.117	3.114	3.112
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
HP Separator - Vessel Pressure Drop [psi]	103.7	113.7	123.7	133.7	143.7	153.7	163.7
Crude for Storage - Calculator (Reid VP at 37....	1.220	1.219	1.218	1.216	1.215	1.213	1.212
Crude for Storage - Calculator (True VP at 37....	3.109	3.106	3.104	3.101	3.098	3.095	3.092
State	State 15						
HP Separator - Vessel Pressure Drop [psi]	173.7						
Crude for Storage - Calculator (Reid VP at 37....	1.210						
Crude for Storage - Calculator (True VP at 37....	3.089						

Table 17. Cendor 2 (H15) Well HP Separator - Pressure Drop (Psia) (Fig.23, Pg.56)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
LP Separator - Vessel Pressure Drop [psi]	0.0000	5.000	10.00	15.00	20.00	25.00	30.00
Crude for Storage - Calculator (Reid VP at 37....	15.37	14.45	13.52	12.60	11.67	10.73	9.792
Crude for Storage - Calculator (True VP at 37....	59.32	55.45	51.58	47.72	43.86	40.00	36.16
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
LP Separator - Vessel Pressure Drop [psi]	35.00	40.00	45.00	50.00	55.00	60.00	65.00
Crude for Storage - Calculator (Reid VP at 37....	8.846	7.893	6.932	5.960	4.973	3.967	2.931
Crude for Storage - Calculator (True VP at 37....	32.32	28.50	24.61	20.70	16.79	12.89	9.001
State	State 15	State 16					
LP Separator - Vessel Pressure Drop [psi]	70.00	75.00					
Crude for Storage - Calculator (Reid VP at 37....	1.842	0.6366					
Crude for Storage - Calculator (True VP at 37....	5.143	1.378					

Table 18. Cendor 2 (H15) Well LP Separator - Pressure Drop (Psia) (Fig.26, Pg.59)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Crude Dehydrator - Vessel Pressure Drop [psi]	0.0000	5.000	10.00	15.00	20.00	25.00	30.00
Crude for Storage - Calculator (Reid VP at 37....	16.03	15.28	14.50	13.71	12.91	12.09	11.25
Crude for Storage - Calculator (True VP at 37....	68.00	63.92	59.88	55.86	51.87	47.90	43.97
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Crude Dehydrator - Vessel Pressure Drop [psi]	35.00	40.00	45.00	50.00	55.00	60.00	65.00
Crude for Storage - Calculator (Reid VP at 37....	10.40	9.530	8.647	7.747	6.831	5.896	4.938
Crude for Storage - Calculator (True VP at 37....	40.06	36.17	32.31	28.47	24.65	20.82	16.87
State	State 15	State 16	State 17	State 18			
Crude Dehydrator - Vessel Pressure Drop [psi]	70.00	75.00	80.00	85.00			
Crude for Storage - Calculator (Reid VP at 37....	3.953	2.930	1.846	0.6386			
Crude for Storage - Calculator (True VP at 37....	12.93	9.024	5.154	1.387			

Table 19.Cendor 2 (H15) Well Degasser - Pressure Drop (Psia) (Fig.29, Pg.62)

DATA TABLES OF SIMULATIONS USING CHAO - SEADER AS FLUID PACKAGE.

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well HP - Std Ideal Liq Vol Fl...	0.0000	1000	2000	3000	4000	5000	6000
Crude for Storage - Calculator (Reid VP at 37....	1.139	1.149	1.159	1.168	1.177	1.185	1.192
Crude for Storage - Calculator (True VP at 37....	2.942	2.962	2.980	2.996	3.011	3.025	3.037
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well HP - Std Ideal Liq Vol Fl...	7000	8000	9000	10000.	1.100e+004	1.200e+004	1.300e+004
Crude for Storage - Calculator (Reid VP at 37....	1.199	1.205	1.211	1.216	1.221	1.226	1.231
Crude for Storage - Calculator (True VP at 37....	3.049	3.060	3.071	3.082	3.091	3.101	3.109
State	State 15	State 16	State 17	State 18	State 19	State 20	State 21
Cendor 2 (H15) Well HP - Std Ideal Liq Vol Fl...	1.400e+004	1.500e+004	1.600e+004	1.700e+004	1.800e+004	1.900e+004	2.000e+004
Crude for Storage - Calculator (Reid VP at 37....	1.235	1.239	1.243	1.247	1.251	1.254	1.257
Crude for Storage - Calculator (True VP at 37....	3.117	3.126	3.133	3.140	3.147	3.154	3.160

Table 20.Cendor 2 Well HP - Std Ideal Liq Vol Flow (barrel/day) (Fig.8, Pg.41)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well LP - Std Ideal Liq Vol Flo...	0.0000	1000	2000	3000	4000	5000	6000
Crude for Storage - Calculator (Reid VP at 37....	1.343	1.333	1.324	1.316	1.309	1.302	1.296
Crude for Storage - Calculator (True VP at 37....	3.304	3.288	3.273	3.259	3.248	3.236	3.225
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well LP - Std Ideal Liq Vol Flo...	7000	8000	9000	10000.	1.100e+004	1.200e+004	1.300e+004
Crude for Storage - Calculator (Reid VP at 37....	1.290	1.285	1.280	1.275	1.271	1.267	1.263
Crude for Storage - Calculator (True VP at 37....	3.215	3.206	3.198	3.190	3.183	3.176	3.169
State	State 15	State 16	State 17	State 18	State 19	State 20	State 21
Cendor 2 (H15) Well LP - Std Ideal Liq Vol Flo...	1.400e+004	1.500e+004	1.600e+004	1.700e+004	1.800e+004	1.900e+004	2.000e+004
Crude for Storage - Calculator (Reid VP at 37....	1.260	1.256	1.253	1.250	1.248	1.245	1.242
Crude for Storage - Calculator (True VP at 37....	3.163	3.157	3.152	3.146	3.141	3.136	3.132

Table 21. Cendor 2 Well LP - Std Ideal Liq Vol Flow (barrel/day) (Fig.10, Pg.42)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well Freewater HP - Std Ideal...	500.0	1000	1500	2000	2500	3000	3500
Crude for Storage - Calculator (Reid VP at 37....	1.249	1.249	1.249	1.249	1.249	1.249	1.250
Crude for Storage - Calculator (True VP at 37....	3.142	3.143	3.143	3.144	3.145	3.145	3.146
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well Freewater HP - Std Ideal...	4000	4500	5000	5500	6000	6500	7000
Crude for Storage - Calculator (Reid VP at 37....	1.250	1.250	1.250	1.250	1.251	1.251	1.251
Crude for Storage - Calculator (True VP at 37....	3.147	3.148	3.148	3.149	3.150	3.150	3.151
State	State 15	State 16	State 17	State 18	State 19	State 20	
Cendor 2 (H15) Well Freewater HP - Std Ideal...	7500	8000	8500	9000	9500	10000.	
Crude for Storage - Calculator (Reid VP at 37....	1.251	1.251	1.252	1.252	1.252	1.252	
Crude for Storage - Calculator (True VP at 37....	3.152	3.152	3.153	3.154	3.154	3.155	

Table 22.Cendor 2 Well Freewater HP - Std Ideal Liq Vol Flow (barrel/day) (Fig.12, Pg.44)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well Freewater LP- - Std Idea...	500.0	1000	1500	2000	2500	3000	3500
Crude for Storage - Calculator (Reid VP at 37....	1.263	1.257	1.252	1.246	1.241	1.237	1.232
Crude for Storage - Calculator (True VP at 37....	3.176	3.163	3.150	3.138	3.127	3.116	3.106
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well Freewater LP- - Std Idea...	4000	4500	5000	5500	6000	6500	7000
Crude for Storage - Calculator (Reid VP at 37....	1.228	1.224	1.220	1.217	1.213	1.210	1.207
Crude for Storage - Calculator (True VP at 37....	3.096	3.087	3.080	3.071	3.062	3.055	3.048
State	State 15	State 16	State 17	State 18	State 19	State 20	
Cendor 2 (H15) Well Freewater LP- - Std Idea...	7500	8000	8500	9000	9500	10000.	
Crude for Storage - Calculator (Reid VP at 37....	1.204	1.201	1.198	1.196	1.193	1.191	
Crude for Storage - Calculator (True VP at 37....	3.042	3.035	3.029	3.024	3.018	3.013	

Table 23.Cendor 2 Well Freewater LP - Std Ideal Liq Vol Flow (barrel/day) (Fig.14, Pg.46)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well HP - Temperature [C]	10.00	15.00	20.00	25.00	30.00	35.00	40.00
Crude for Storage - Calculator (Reid VP at 37....	1.252	1.253	1.253	1.253	1.252	1.252	1.252
Crude for Storage - Calculator (True VP at 37....	3.155	3.154	3.153	3.152	3.150	3.149	3.148
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well HP - Temperature [C]	45.00	50.00	55.00	60.00	65.00	70.00	75.00
Crude for Storage - Calculator (Reid VP at 37....	1.251	1.250	1.250	1.249	1.248	1.247	1.246
Crude for Storage - Calculator (True VP at 37....	3.147	3.146	3.145	3.143	3.143	3.142	3.141
State	State 15	State 16	State 17	State 18	State 19		
Cendor 2 (H15) Well HP - Temperature [C]	80.00	85.00	90.00	95.00	100.0		
Crude for Storage - Calculator (Reid VP at 37....	1.245	1.244	1.243	1.241	1.240		
Crude for Storage - Calculator (True VP at 37....	3.140	3.140	3.140	3.139	3.139		

Table 24. Cendor 2 Well HP - Temperature (°C) (Fig.16, Pg.49)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well LP - Temperature [C]	10.00	15.00	20.00	25.00	30.00	35.00	40.00
Crude for Storage - Calculator (Reid VP at 37....	1.925	1.853	1.786	1.721	1.660	1.601	1.545
Crude for Storage - Calculator (True VP at 37....	4.796	4.612	4.439	4.276	4.123	3.979	3.841
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well LP - Temperature [C]	45.00	50.00	55.00	60.00	65.00	70.00	75.00
Crude for Storage - Calculator (Reid VP at 37....	1.491	1.439	1.389	1.341	1.294	1.249	1.205
Crude for Storage - Calculator (True VP at 37....	3.711	3.586	3.469	3.356	3.248	3.143	3.044
State	State 15	State 16	State 17	State 18	State 19		
Cendor 2 (H15) Well LP - Temperature [C]	80.00	85.00	90.00	95.00	100.0		
Crude for Storage - Calculator (Reid VP at 37....	1.163	1.121	1.081	1.042	1.005		
Crude for Storage - Calculator (True VP at 37....	2.949	2.858	2.768	2.684	2.602		

Table 25. Cendor 2 Well LP - Temperature (°C) (Fig.18, Pg.50)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well HP - Pressure [psia]	300.0	800.0	1300	1800	2300	2800	3300
Crude for Storage - Calculator (Reid VP at 37....	1.241	1.250	1.250	1.250	1.250	1.249	1.249
Crude for Storage - Calculator (True VP at 37....	3.127	3.145	3.145	3.145	3.144	3.144	3.144
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well HP - Pressure [psia]	3800	4300	4800	5300	5800	6300	6800
Crude for Storage - Calculator (Reid VP at 37....	1.249	1.248	1.248	1.247	1.247	1.247	1.247
Crude for Storage - Calculator (True VP at 37....	3.144	3.143	3.143	3.142	3.142	3.142	3.142
State	State 15	State 16	State 17	State 18	State 19	State 20	
Cendor 2 (H15) Well HP - Pressure [psia]	7300	7800	8300	8800	9300	9800	
Crude for Storage - Calculator (Reid VP at 37....	1.246	1.246	1.246	1.245	1.245	1.245	
Crude for Storage - Calculator (True VP at 37....	3.142	3.141	3.141	3.141	3.141	3.140	

Table 26.Cendor 2 Well HP - Pressure (Psia) (Fig.20, Pg.51)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Cendor 2 (H15) Well LP - Pressure [psia]	156.0	656.0	1156	1656	2156	2656	3156
Crude for Storage - Calculator (Reid VP at 37....	0.2769	1.327	1.346	1.335	1.324	1.314	1.303
Crude for Storage - Calculator (True VP at 37....	0.4511	3.324	3.367	3.342	3.317	3.292	3.268
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Cendor 2 (H15) Well LP - Pressure [psia]	3656	4156	4656	5156	5656	6156	6656
Crude for Storage - Calculator (Reid VP at 37....	1.292	1.257	1.229	1.209	1.193	1.181	1.169
Crude for Storage - Calculator (True VP at 37....	3.242	3.162	3.099	3.052	3.018	2.990	2.964
State	State 15	State 16	State 17	State 18	State 19	State 20	
Cendor 2 (H15) Well LP - Pressure [psia]	7156	7656	8156	8656	9156	9656	
Crude for Storage - Calculator (Reid VP at 37....	1.159	1.148	1.138	1.128	1.118	1.107	
Crude for Storage - Calculator (True VP at 37....	2.941	2.916	2.893	2.871	2.849	2.826	

Table 27.Cendor 2 Well LP - Pressure (Psia) (Fig.22, Pg.54)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
HP Separator - Vessel Pressure Drop [psi]	33.70	43.70	53.70	63.70	73.70	83.70	93.70
Crude for Storage - Calculator (Reid VP at 37....	1.258	1.257	1.254	1.252	1.250	1.248	1.246
Crude for Storage - Calculator (True VP at 37....	3.166	3.162	3.157	3.152	3.147	3.142	3.137
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
HP Separator - Vessel Pressure Drop [psi]	103.7	113.7	123.7	133.7	143.7	153.7	163.7
Crude for Storage - Calculator (Reid VP at 37....	1.244	1.241	1.239	1.237	1.234	1.232	1.229
Crude for Storage - Calculator (True VP at 37....	3.132	3.127	3.122	3.116	3.111	3.106	3.102
State	State 15						
HP Separator - Vessel Pressure Drop [psi]	173.7						
Crude for Storage - Calculator (Reid VP at 37....	1.226						
Crude for Storage - Calculator (True VP at 37....	3.095						

Table 28.Cendor 2 Well HP Separator - Pressure Drop (Psia) (Fig.24, Pg.57)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
LP Separator - Vessel Pressure Drop [psi]	0.0000	5.000	10.00	15.00	20.00	25.00	30.00
Crude for Storage - Calculator (Reid VP at 37....	15.44	14.50	13.56	12.61	11.67	10.72	9.769
Crude for Storage - Calculator (True VP at 37....	57.57	53.81	50.06	46.31	42.57	38.84	35.12
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
LP Separator - Vessel Pressure Drop [psi]	35.00	40.00	45.00	50.00	55.00	60.00	65.00
Crude for Storage - Calculator (Reid VP at 37....	8.817	7.860	6.899	5.930	4.950	3.955	2.932
Crude for Storage - Calculator (True VP at 37....	31.40	27.70	24.01	20.27	16.47	12.68	8.899
State	State 15	State 16					
LP Separator - Vessel Pressure Drop [psi]	70.00	75.00					
Crude for Storage - Calculator (Reid VP at 37....	1.859	0.6657					
Crude for Storage - Calculator (True VP at 37....	5.132	1.424					

Table 29. Cendor 2 Well LP Separator - Pressure Drop (Psia) (Fig.26, Pg.59)

State	State 1	State 2	State 3	State 4	State 5	State 6	State 7
Crude Dehydrator - Vessel Pressure Drop [psi]	0.0000	5.000	10.00	15.00	20.00	25.00	30.00
Crude for Storage - Calculator (Reid VP at 37....	16.31	15.51	14.69	13.86	13.02	12.16	11.29
Crude for Storage - Calculator (True VP at 37....	66.49	62.44	58.44	54.47	50.55	46.65	42.79
State	State 8	State 9	State 10	State 11	State 12	State 13	State 14
Crude Dehydrator - Vessel Pressure Drop [psi]	35.00	40.00	45.00	50.00	55.00	60.00	65.00
Crude for Storage - Calculator (Reid VP at 37....	10.42	9.529	8.631	7.721	6.800	5.865	4.913
Crude for Storage - Calculator (True VP at 37....	38.97	35.17	31.41	27.67	23.97	20.28	16.55
State	State 15	State 16	State 17	State 18			
Crude Dehydrator - Vessel Pressure Drop [psi]	70.00	75.00	80.00	85.00			
Crude for Storage - Calculator (Reid VP at 37....	3.939	2.930	1.863	0.6676			
Crude for Storage - Calculator (True VP at 37....	12.73	8.920	5.142	1.433			

Table 30.Cendor 2 Well Degasser - Pressure Drop (Psia) (Fig.30, Pg.63)

APPENDIX IV

STANDARD CONDITIONS OF THE SIMULATION

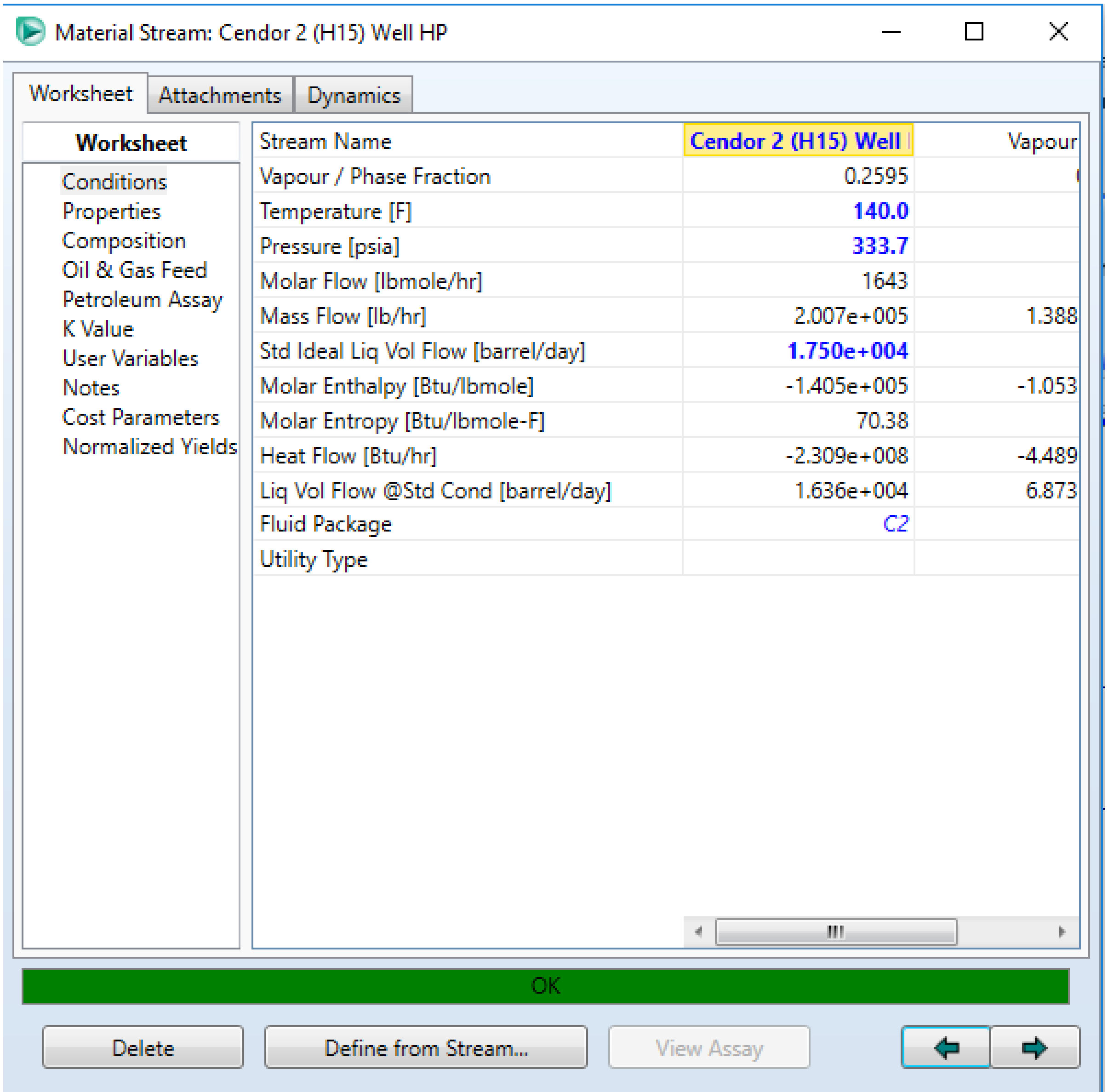

Figure 41. Standard Condition of Crude Oil coming from High Pressure Well

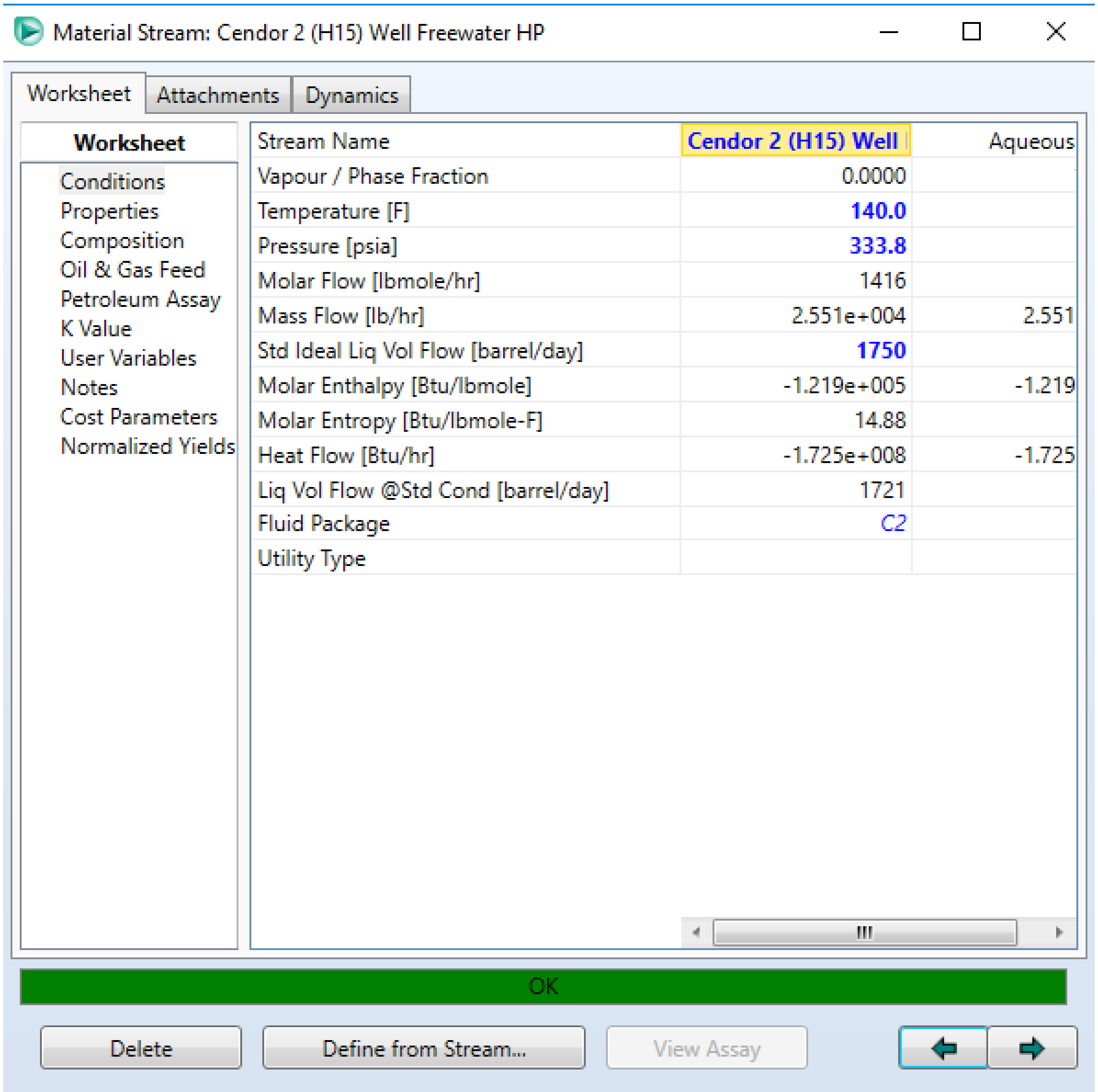

Figure 42. Standard Condition of Free Water coming from High Pressure Well

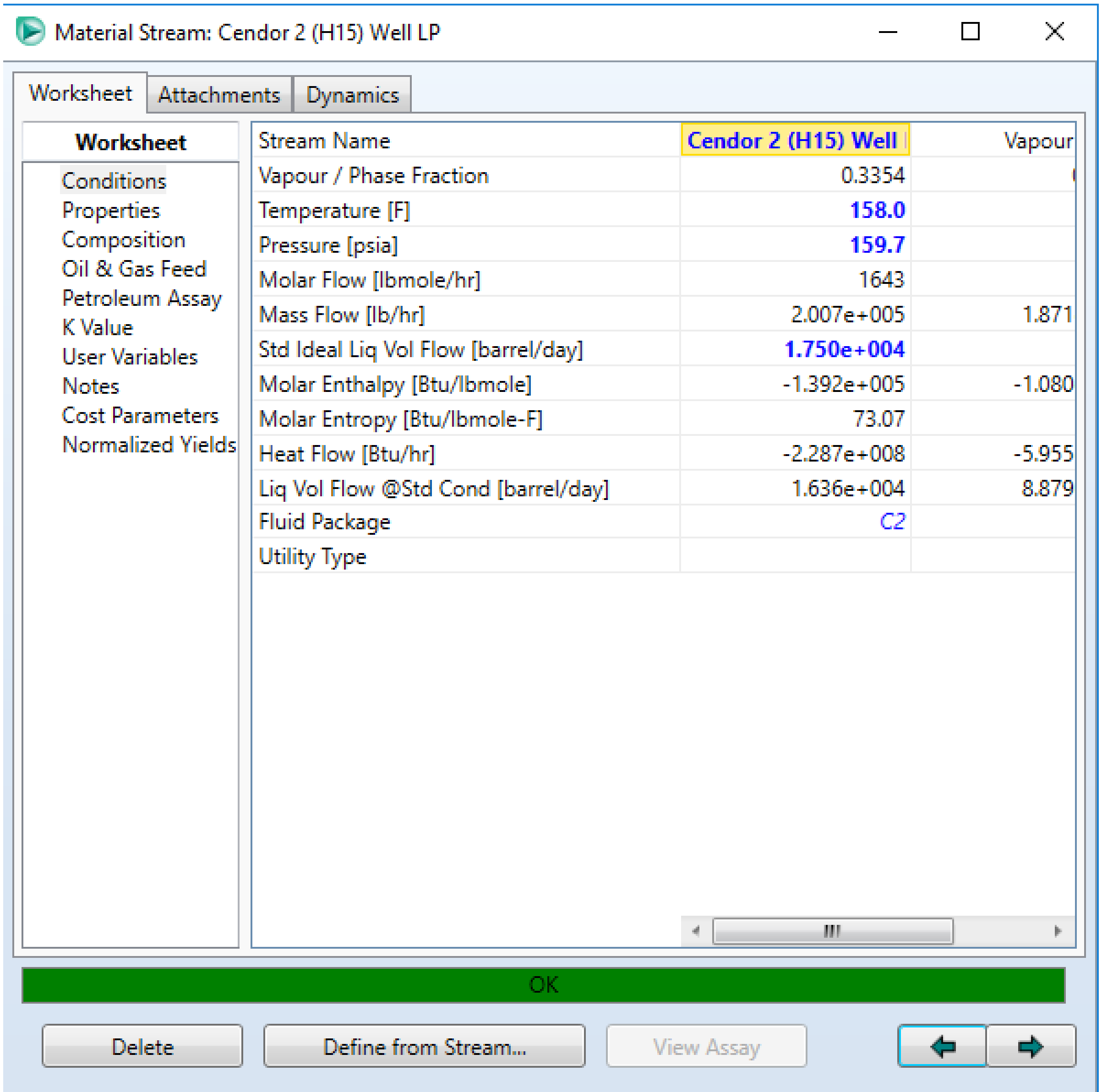

Figure 43. Standard Condition of Crude Oil coming from Low Pressure Well

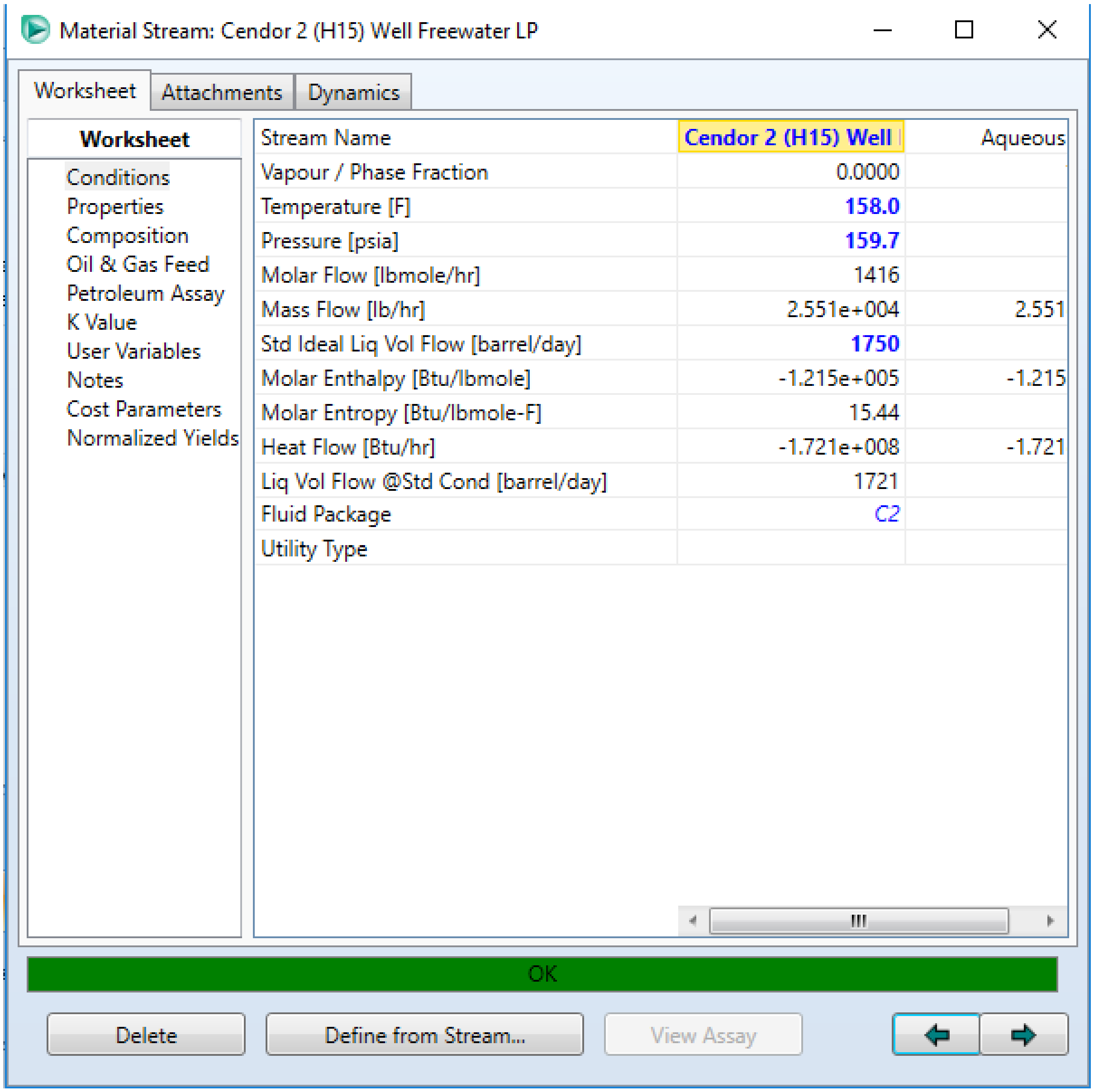

Figure 44. Standard Condition of Free Water coming from Low Pressure Well

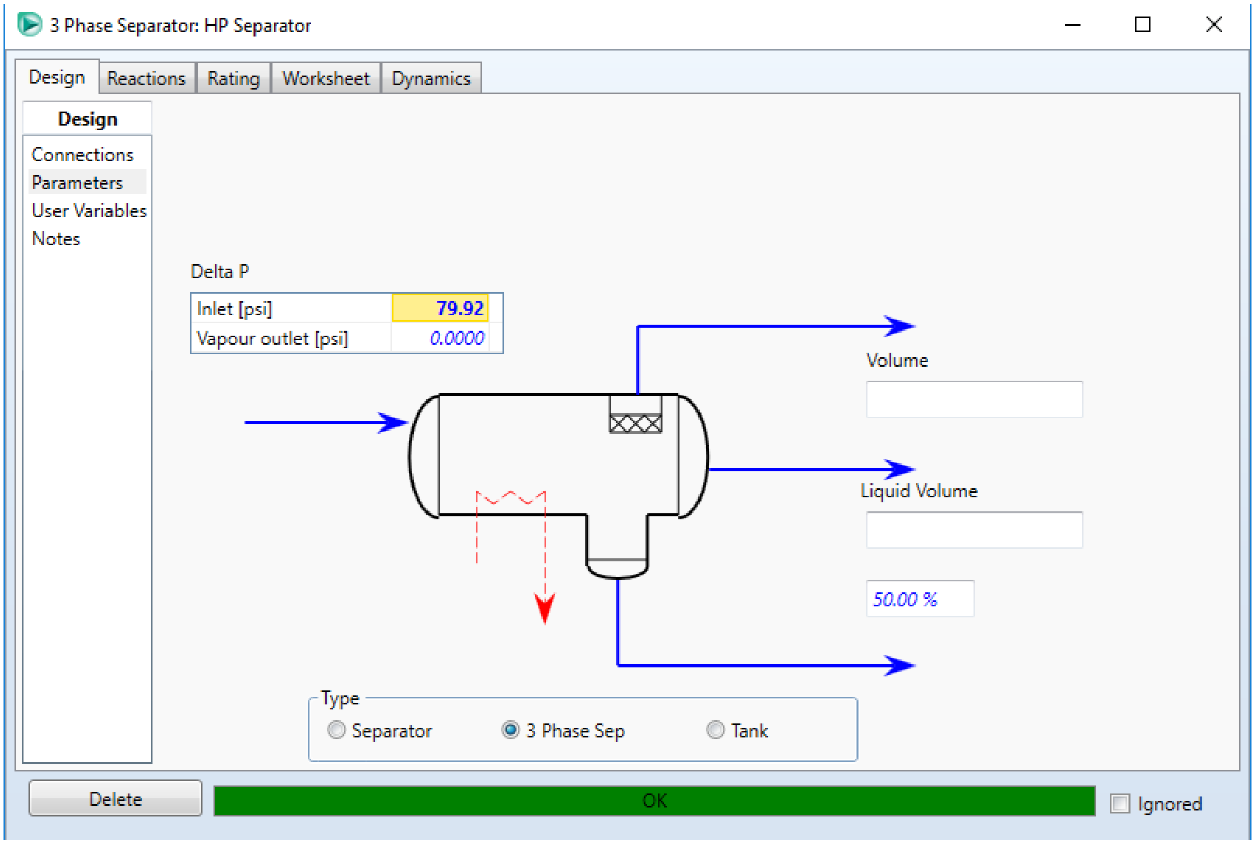

Figure 45. Design Parameters of High Pressure Separator

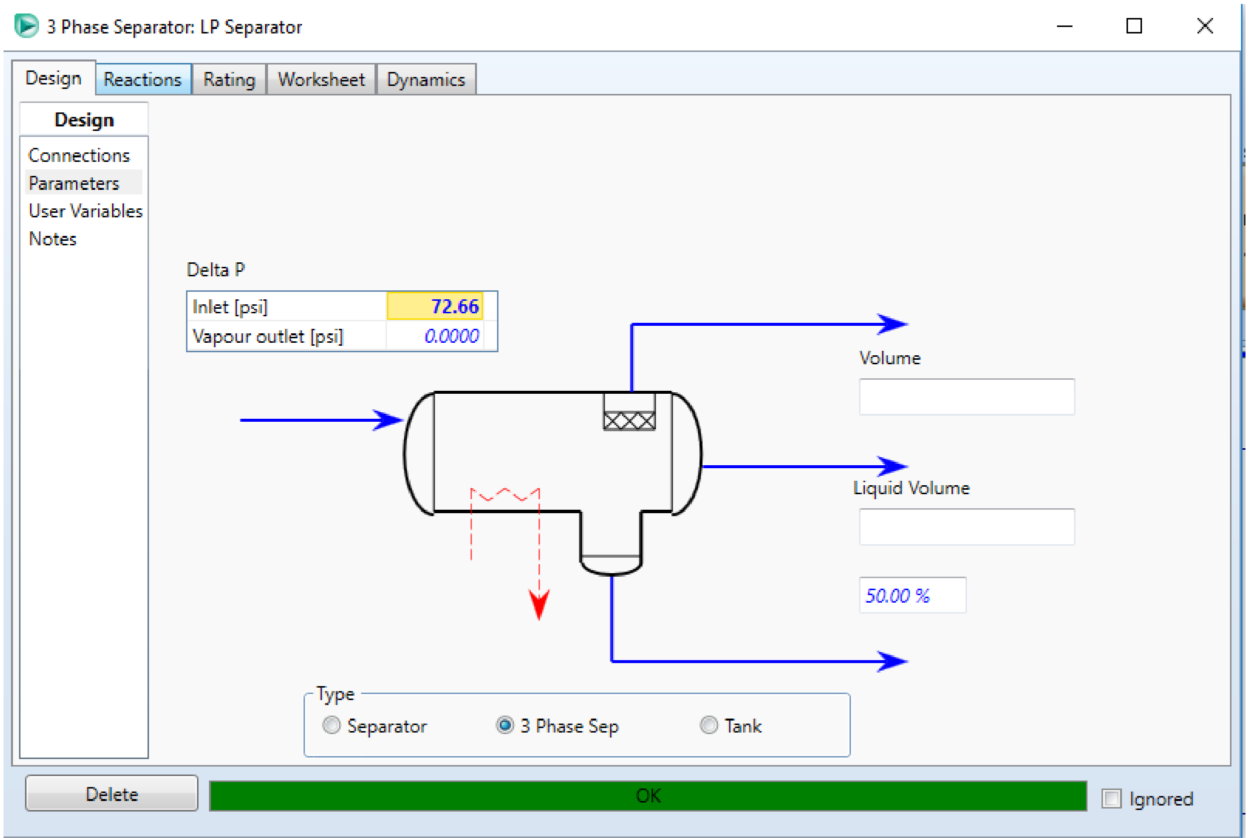

Figure 46. Design Parameter of Low Pressure Separator

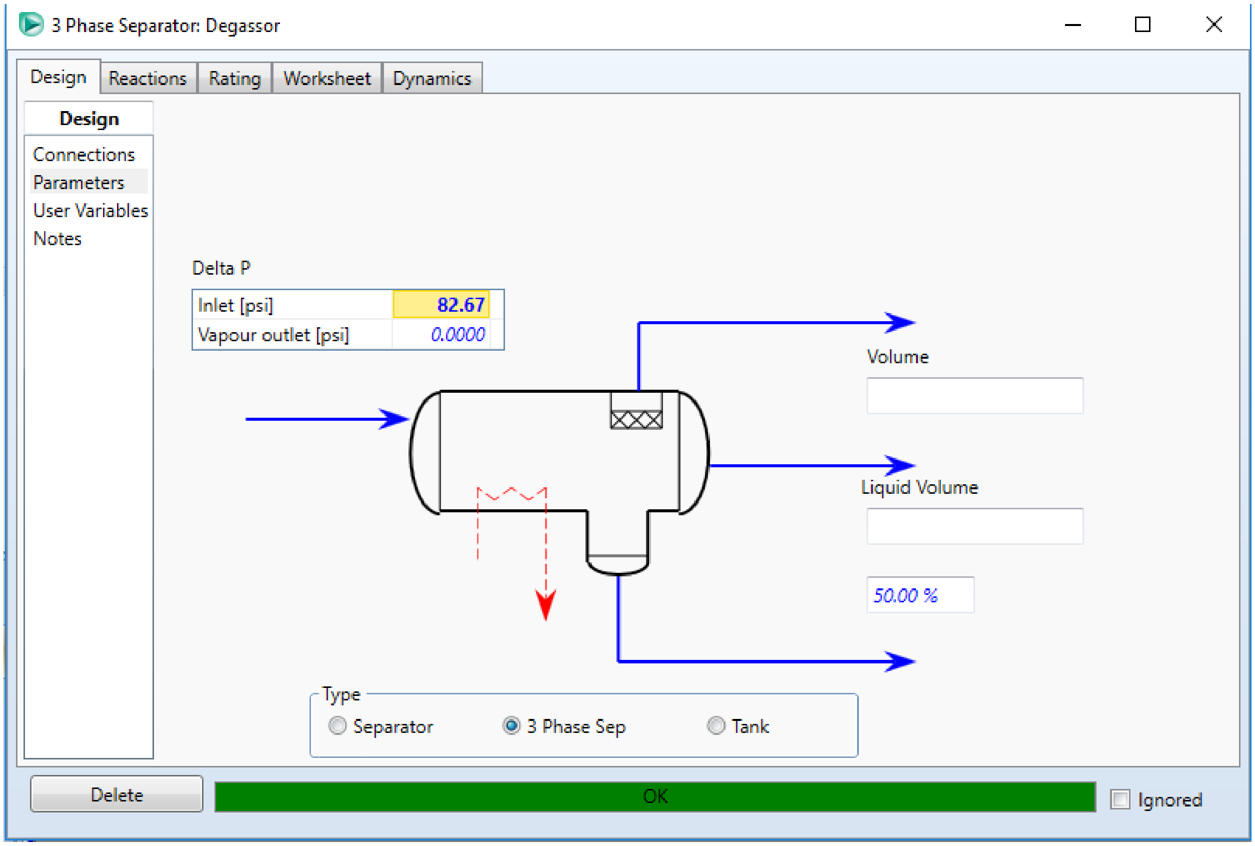

Figure 47. Design Parameters of Degasser.

APPENDIX V

CERTIFICATE OF ORIGINALITY

I declare that,

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no part of this Master Thesis / Degree Thesis (*choose one*) is taken from other people's work without giving them credit,

all references have been clearly cited,

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I understand that an infringement of this declaration leaves me subject to the foreseen disciplinary actions by *The Universitat Politècnica de Catalunya - BarcelonaTECH*.

Amirul Asyraff Bin Othman	Amirul	15/9/19
Student Name	Signature	Date

Title of the Thesis : Simulation and Design of the Topside of a Floating Production, Storage and Offloading vessel. (FPSO) (Crude Stabilization Process)